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STATISTICAL EVALUATION OF GRADATION TEST RESULTS FOR BASE AND SUBBASE AGGREGATES 1980 CONSTRUCTION SEASON

Engineering
Materials
Office

STATISTICAL EVALUATION OF GRADATION TEST RESULTS

FOR

BASE AND SUBBASE AGGREGATES

1980 CONSTRUCTION SEASON

by

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1. INTRODUCTION

Statistical concepts of quality assurance were introduced in 1979 for the acceptance of granular base and subbase aggregates. Since the use of statistics was new to the Ministry, it was planned that the full implementation of such a program would be gradual, taking several years to complete.

The 1979 Guidelines for acceptance and rejection of granular materials by gradation tests introduced random sampling, the concept of lots and sublots, and acceptance based on the average of four tests within a lot. After an evaluation of the 1979 gradation results, new guidelines were issued for the 1980 construction season (1980 guidelines attached in Appendix 'A'). The guidelines introduc ed an acceptable range of the four sublots within a lot to be used with the mean criterion as the requirements for lot acceptance. As a further step, acceptance of slightly out of specification lots was allowed with an appropriately adjusted payment.

During the 1980 construction season all gradation test results received for granular base and subbase aggregates were analysed by this office. It was felt that the analysis of the large amount of data would serve as excellent feedback information, and would enable us to develop end result specifications or special provisions based on statistical parameters. By reporting the results of the 1980 gradation tests, Regional construction personnel as well as Contractors and Aggregate Producers would have a fairly good knowledge of the various aggregates produced at commerical and wayside pits and quarries. The description of the methodology used throughout the analysis would assist Regional Quality Assurance personnel to carry out similar work for their particular area in the future.

2. OBJECTIVES AND SCOPE OF PROJECT

2.1 Analyse and evaluate the gradation tests for granular base and subbase aggregates that were received during the 1980 construction season in order to obtain statistical parameters.

2.2 Provide feedback information to Regional Quality Assurance and Construction Staff, and also to make it available to producers and contractors.

2.3 Describe in detail the methodology used for statistical analysis in order to assist Regional personnel to carry out similar analysis for prospective aggregate sources in the future.

3. ANALYSIS OF RESULTS

3.1 Collection of Data

The collection of data was made possible by the "Granular Gradation Test Computation Sheet", form PR-D-1, being completed for each test within a lot for all contracts. The Soils and Aggregates canary copy was submitted to Head Office, Soils and Aggregates Section by the Regions. The 1980 test data, received by this Section up to the middle of January 1981, was used for evaluation in this report.

3.2 Organization of Data

To evaluate and analyse data requires the organization and recording of results for meaningful interpretation. It was decided to organize the data first by material type and then by material source for each region. An in-house form was designed for recording material type and source, contract number, lot number, lot values (mean percent passing) and range of individual tests within a lot for each designated sieve.

This form shows the specification band and acceptable range values and indicates if the lot was accepted, rejected or accepted with adjusted payment. Figure 1 shows a granular 'A' recording form.

GRADATION TEST DATA - 1980 LOT VALUES

GRANULAR TYPE A

MATERIAL SOURCE _____ MIN AGG INV CODE Nº _____ REGION _____

CONTRACT NUMBER	LOT Nº	DESIGNATED SIEVES AND SPECIFICATIONS														TOTAL ADJUST POINTS	LOT			REMARKS
		37.5 mm		16.0 mm		9.5 mm		4.75 mm		1.18 mm		300 µm		75 µm			ACCEPT	ADJUST	REJECT	
		99-100	R-2	62-100	R-38	48-73	R-25	33-55	R-22	15-45	R-30	5-22	R-17	0-8*	R-8					

* Where material is obtained from a rock quarry source, 10% passing the 75 µm sieve will be permitted

Fig. 1

Regional summaries were carried out for all sources that had at least four lots or more. This data was tabulated by source, showing the number of lots, the mean and standard deviation for each designated sieve as well as the number of non conforming lots for each source. Figure 2 shows the Granular 'A' Summary form.

SUMMARY OF GRANULAR 'A' SOURCES - 1980 CONSTRUCTION SEASON _____ REGION

SOURCE (Min. of 4 lots)	LOT n	DESIGNATED SIEVES																	
		16.0 mm			9.5 mm			4.75 mm			1.18 mm			300 µm			75 µm		
		$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC

NC = Non Conforming Lots ( ) Indicates Non Conformance On Range

Fig. 2

Provincial summaries were performed on gradation as well as the range of individual tests within a lot. To assist analyses of the overall results, frequency tables and histograms were developed. Guidelines for frequency table development and some examples are included in Appendix 'B' of this report.

3.3 Analysis of Data

Once the data is properly organized, it is possible to extract a considerable amount of information from it by using proper analysis techniques. Tables or histograms which provide simple classifications of data do not always reveal or describe the important characteristics of the data in a

satisfactory manner; therefore, it is necessary to compute statistical measures which describes these characteristics.

The two most important properties of a set organized data is the mean ($\bar{X}$) and the standard deviation (σ). The mean and standard deviation were calculated for each designated sieve, for each type of material and for all sources from which data was received. As most sources had fewer than thirty lots of analyse, all calculations were performed using a Texas Instrument (TI-55) calculator, using the procedure shown in Appendix 'C', (page C-4).

Analysis equations for individual ungrouped data as well as grouped sample data, along with step by step procedures for performing the calculations, are included in Appendix 'C' of this report.

When analysing large amounts of data (50 or more) such as Regional summaries or all the individual tests from a single source, it may be practical to develop frequency tables and use the group data method of calculating the mean and standard deviation. A program for group data was developed for use with the Texas Instrument TI-55 calculator and is included in Appendix 'C', (page C-5).

3.4 Interpretation of Data

In this part of the statistical analysis, the basic sample data results are interpreted and extended into more general, broader statements about the population or the lot of material that has been produced. The assumption of a normal distribution is sufficiently valid for highway construction purposes provided that the data is obtained under controlled conditions and sampled randomly. The statistical properties of mean and standard deviation are used with 'Z' tables for areas under a normal curve to estimate the percent within specifications for

all sample data. Illustations, formulas and 'Z' tables for areas under a normal curve as well as example calculations can be found in Appendix 'D'.

In the interpretation of the data used, and specifically the regional summaries for material sources, it must be remembered that the sample data for gradation test results is the lot value (average of four tests) and not individual test results. Therefore, estimates of percent within specification will refer to the percentage of lot values within specification and not the overall population of the material.

Where the mean ($\overline{X}$) value for lots will be the same as for individual test data, the dispersion or standard deviation (σ) of the lot values will be approximately one half the dispersion expected for individual test results. Statistically the dispersion for means of four tests is exactly one half the dispersion of individuals, as per the following formula

$$\sigma_{\overline{X}} = \frac{\sigma}{\sqrt{n}}$$

where: $\sigma_{\overline{X}}$ = Standard error of the mean (Standard deviation of more than one test)

σ = Standard deviation (sublot test)

$\sqrt{n}$ = Square root of the number of sublots in a lot

In actual fact, we have found that in most cases the standard deviation for lot values is slightly more than half the individual values. If a more accurate estimate of percent within specification for the material from each source is required an analysis of all the individual tests will have to be carried out.

4. DISCUSSION AND EVALUATION OF SAMPLE DATA

Regional Analyses and Summaries contain those sources that had at least four lots of material. Sources with one, two or three lots were not included for statistical analysis.

The data used for the analysis and summaries was assumed to be from acceptable lots. Non conforming lots that had no comments or remarks were considered as accepted, only the data marked as rejected or unacceptable were omitted from being evaluated, as this material was not used for Ministry contracts.

4.1 Central Region

4.1.1 Base Course Aggregates

Granular A: Some twenty-three sources and a total of three hundred and fifty lots were analysed. For each source the number of lots, the mean, standard deviation and the number of non conforming lots are shown for each designated sieve. This data is presented in tabular form on Figure 3.

The sources are summarized in three separate groups as follows: eighteen sources produced 22.4 mm max. size material and one source produced 37.5 mm max. size material from pits and four sources produced 22.4 mm max. size from quarries. Summary totals indicate total number of lots, a weighted mean, a weighted average standard deviation and the total of non conforming lots. Of the three hundred and fifty lots analysed, twenty-one were considered to be non conforming. Of the seven non conforming lots on the 9.5 mm sieve, five were from 1979 contracts in which this sieve was not specified. The six non conforming lots on the 1.18 mm sieve were from one source, and only two lots were non conforming on the range. When the suggested adjustment point (Appendix E) penalties were applied to the non conforming lots, twenty of the twenty-one lots would have had less than 5 adjustment points each. Therefore, most of the non conforming lots accepted were marginal.

16 mm Crushed Type 'A' and 'B': no data received.

4.1.2 Subbase Materials

Granular B: Central Region was the main user of this meterial with seven sources being analysed. The results and summary are presented on Figure 4.

Of the fifty four lots analysed, four were considered non conforming on gradation, and three lots did not meet the

SUMMARY OF GRANULAR 'A' SOURCES - 1980 CONSTRUCTION SEASON

CENTRAL REGION

SOURCE (Min. of 4 lots)	LOT n	DESIGNATED SIEVES																		
		16.0 mm			9.5 mm			4.75 mm			1.18 mm			300 µm			75 µm		
		$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC
PITS (22.4 mm)																			
Ambro-Caledon	18	86.8	2.0	0	65.0	4.1	0	47.1	4.5	(1)	28.3	3.7	0	12.1	2.2	0	5.5	2.1	0
Caledon S & G	9	87.1	1.1	0	66.3	2.2	0	49.0	3.2	0	29.9	2.6	0	11.6	2.1	0	5.1	1.3	0
James Dick	11	85.6	2.7	0	65.1	3.3	0	49.4	3.4	1	32.1	2.7	0	13.3	1.4	0	6.9	0.7	1
Franceschini	8	83.2	2.5	0	64.6	2.4	0	50.0	3.1	0	33.6	1.9	0	16.9	1.2	0	7.3	0.5	0
Giordano	14	86.1	3.1	0	63.3	4.7	0	47.3	3.9	0	31.3	3.8	0	12.3	3.4	0	3.5	0.5	0
Hancock	25	85.9	2.3	0	63.1	3.3	0	47.3	3.9	0	31.7	5.1	0	15.1	3.0	0	5.6	1.0	0
Harnden & King#22	4	89.7	2.9	0	67.6	3.2	0	51.2	0.8	0	32.0	2.6	0	16.2	1.0	0	3.8	0.4	0
Moyer	5	96.9	1.0	0	72.3	3.4	1	41.1	2.8	0	28.4	2.6	0	14.6	0.9	0	6.5	0.6	0
National Slag	13	92.9	1.8	0	67.5	5.3	1	45.4	5.0	0	22.5	3.0	0	11.1	1.7	0	4.4	0.7	0
Nameth	13	89.9	2.2	0	68.8	2.7	1	50.9	2.8	0	32.2	2.8	0	10.4	1.9	0	5.5	1.3	0
Nesbit	27	86.5	2.8	0	65.0	4.1	1	48.6	4.2	(1)	32.3	3.0	0	10.8	1.8	0	3.7	1.0	0
Odorico	8	90.8	2.0	0	68.0	3.1	0	48.9	2.4	0	22.4	1.5	0	10.7	1.7	0	6.5	1.0	0
O'Neill	10	88.6	2.4	0	65.8	4.1	1	46.0	2.1	0	23.5	3.0	0	9.1	1.2	0	3.0	0.5	0
O'Reilly	14	85.2	3.2	0	64.2	2.8	0	50.6	3.2	0	36.6	3.9	0	13.2	2.5	0	4.4	0.6	0
Pilutti	46	86.4	3.0	0	61.7	4.4	0	42.1	4.3	0	18.1	2.4	6	9.6	1.3	0	6.2	0.6	0
Preston	16	89.9	1.7	0	70.2	3.3	1	48.6	4.4	0	26.7	3.9	0	8.9	2.2	0	4.0	0.9	0
Repac Pit #27	18	90.2	1.7	0	65.6	2.6	0	48.7	3.0	0	33.6	2.3	0	14.2	2.2	0	3.6	0.5	0
Smith	27	89.3	1.6	0	65.7	3.4	0	47.0	4.3	1	32.1	4.9	0	16.4	2.0	0	4.7	0.7	0
Summary	*286*	*87.8*	*2.4*	*0*	*66.0*	*3.7*	*6*	*47.2*	*3.9*	*2 (2)*	*28.5*	*3.4*	*6*	*12.3*	*2.2*	*0*	*5.0*	*0.9*	*2*
PITS (37.5 mm)																			
Vincent	15	78.1	4.5	0	61.9	4.1	0	48.0	4.3	0	20.9	3.3	1	7.7	1.4	0	5.2	0.9	0
QUARRIES (22.4 mm)																			
Gormley	12	87.6	1.6	0	63.7	2.1	0	39.0	1.2	0	18.2	0.9	0	10.0	0.9	0	6.0	0.5	0
Indusmin	29	85.1	6.0	0	59.9	7.2	1	39.4	4.9	1	18.0	3.0	0	10.2	2.0	0	6.7	1.3	1
Lincoln	4	89.3	4.1	0	63.5	4.5	0	42.4	4.2	0	23.2	1.9	0	15.4	2.0	0	9.4	0.2	0
Walker	4	85.7	1.6	0	60.2	4.5	0	39.1	4.1	0	22.4	3.3	0	13.8	2.4	0	8.7	1.1	0
Summary	*49*	*86.2*	*4.8*	*0*	*60.7*	*6.4*	*1*	*39.5*	*4.2*	*1*	*18.8*	*2.6*	*0*	*10.9*	*1.8*	*0*	*6.9*	*1.1*	*1*

NC = Non Conforming Lots ( ) Indicates Non Conformance On Range.

Fig. 3

SUMMARY OF GRANULAR 'B' SOURCES - 1980 CONSTRUCTION SEASON

CENTRAL REGION

SOURCE (Min. of 4 lots)	LOT n	DESIGNATED SIEVES																		
		22.4 mm			4.75 mm			1.18 mm			300 μm			75 μm						
		$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC
Clarke	4	98.2	0.7	0	91.3	4.0	0	74.3	13.4	0	20.9	6.9	0	4.7	1.8	0			
Everson	7	89.9	9.8	0	67.4	13.6	0	42.7	18.6	0	14.3	10.9	(1)	2.7	1.3	0			
Lakeview Gen.Sta.	4	99.0	0.6	0	82.5	1.7	0	51.7	1.7	0	28.8	1.0	0	9.6	0.6	2			
Nemeth	12	83.7	4.8	0	59.6	6.6	0	40.2	13.0	0	11.4	6.9	1 (1)	3.0	1.9	(1)			
Odorico	4	84.8	3.6	0	67.5	4.7	0	31.0	6.0	0	6.9	1.4	0	4.2	1.0	0			
O'Neill	11	80.3	4.1	0	57.5	8.5	0	37.5	11.9	0	16.2	7.0	0	2.9	0.5	0			
Pilutti	12	89.5	2.3	0	65.3	6.4	0	33.3	8.2	0	7.9	2.6	1	4.4	1.0	0			
Summary	*54*	*87.3*	*4.8*	*0*	*66.1*	*7.9*	*0*	*41.1*	*11.9*	*0*	*12.1*	*6.4*	*2 (2)*	*4.0*	*1.3*	*2 (1)*			

Fig. 4

SUMMARY OF GRANULAR 'C' SOURCES - 1980 CONSTRUCTION SEASON

CENTRAL REGION

SOURCE (Min. of 4 lots)	LOT n	DESIGNATED SIEVES																		
		26.5 mm			4.75 mm			1.18 mm			300 μm			150 μm			75 μm			
		$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	
Consolidated	5	98.1	1.3	0	90.0	3.2	0	83.7	2.7	0	52.9	5.4	0	18.7	3.2	0	5.5	1.2	0	
Davey's	4	100.0	0	0	90.9	2.1	0	58.5	4.3	0	[illegible]4.9	4.1	0	12.8	3.6	0	7.8	2.5	0	
James Dick	5	100.0	0	0	98.4	0.7	0	97.8	0.9	0	[illegible]5.9	2.2	0	22.4	9.7	0	5.4	2.8	0	
Gordon Joy	16	96.0	3.4	0	85.4	6.5	0	72.0	10.1	0	26.3	12.3	0	9.7	5.3	1	3.4	1.5	0	
Hancock	33	99.5	0.6	0	97.3	2.5	0	94.7	4.1	0	58.2	8.2	0	17.2	4.4	0	4.0	1.8	0	
Hare	8	90.4	7.2	0	79.2	10.1	0	71.5	10.8	0	44.6	8.3	0	9.7	2.5	0	2.4	0.9	0	
Lee's	31	97.1	2.5	0	87.0	7.5	0	82.3	8.4	0	50.7	6.7	0	19.5	3.7	0	7.0	1.8	1	
Stan McCarthy	7	83.6	2.6	0	51.9	1.7	0	36.8	1.2	0	14.9	1.7	0	5.3	0.3	0	2.6	0.7	0	
O'Reilly	12	81.6	8.3	0	67.2	13.1	0	57.6	16.8	0	23.4	12.3	0	9.7	5.3	0	3.9	1.8	0	
Repac Pit #27	12	94.9	2.8	0	77.0	5.8	0	61.3	5.4	0	26.0	8.2	0	11.9	4.7	0	5.1	1.7	0	
Sherman	4	97.6	1.6	0	82.8	9.5	0	56.6	22.0	0	13.5	3.1	0	8.1	1.7	0	7.1	1.7	0	
Summary	*137*	*86.2*	*3.6*	*0*	*85.0*	*6.8*	*0*	*76.3*	*9.0*	*0*	*42.1*	*8.3*	*0*	*14.5*	*4.5*	*1*	*4.8*	*1.7*	*1*	

NC = Non Conforming Lots ( ) Indicates Non Conformance On Range

Fig. 5

acceptable range criterion. All four non conforming lots on gradation are within 1% or less of the specification. Total adjustment points of the four lots amounted to 2.5. The three lots out on Range were outside by the following amounts: 3, 7 and 8 percent.

Granular C: Eleven sources and some one hundred and thirty-seven lots were analysed. The results and summary are presented in Figure 5. Only two lots were non conforming both for gradation, one being 0.6% out on the 150 µm sieve and the other 0.2% out on the 75 µm sieve for a combined total of 2.6 adjustment points.

4.2 Southwestern Region

4.2.1 Base Course Materials

Granular A: A total of ten sources were analysed. For each source the number of lots, the mean, the standard deviation and the number of non conforming lots are shown for each designated sieve. This data is presented in tabular form on Figure 6. The sources were summarized in three groups. Eight sources were analysed for pit material, 22.4 mm max. size, two quarry sources for 22.4 mm max. size material with one of the quarry sources producing 37.5 mm max. size material.

Summary totals indicate total number of lots, a weighted mean, a weighted average standard deviation and the total of non conforming lots. A total of one hundred and thirty-five lots were analysed, seventy-four lots were produced from one quarry source producing 22.4 mm and 37.5 mm granular 'A' material. The majority of non conforming lots for Southwestern Rgion were from this one source. When producing the 22.4 mm material 25% of the lots were non conforming on the 75 µm sieve and when producing the 37.5 mm material approximately 50% of the lot were non conforming on the 4.75 mm sieve. The grain size distribution for both types of material are shown on Figure 7.

Of the nine remaining sources, sixty-one lots were produced. Five lots were non conforming on gradation, all on the 9.5 mm sieve, four being from one source. Three lots were non conforming on range. All eight non conforming lots had a combined total of 10.5 adjustment points. (Appendix E).

16 mm Crushed Type 'A": no data received

16 mm Crushed Type 'B': Two sources and a total of thirteen lots were analysed. The R. Feagan Pit had seven lots analysed all conforming to specifications, the Morcam Pit had one of its six lots non conforming on the 300 µm sieve due to the gradation being 2.8% above specification.

SUMMARY OF GRANULAR 'A' SOURCES - 1980 CONSTRUCTION SEASON

SOUTHWESTERN REGION

SOURCE (Min. of 4 lots)	LOT n	DESIGNATED SIEVES																	
		16.0 mm			9.5 mm			4.75 mm			1.18 mm			300 μm			75 μm		
		$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC
PIT (22.4 mm)																			
Huron Gravel	7	93.7	1.0	0	70.1	2.0	1	50.0	3.3	0	26.9	2.3	0	12.1	1.3	0	3.7	0.6	0
Huron Ridge	5	96.6	1.9	0	74.3	2.1	4	49.3	1.6	0	30.9	2.1	0	13.1	1.3	0	3.7	0.6	0
Morcam	6	86.5	2.2	0	-	-	-	43.9	3.2	0	28.0	3.0	0	15.2	3.0	0	4.4	0.7	0
Richardson	10	82.7	4.1	0	59.4	5.0	0	45.7	5.3	0	31.7	4.5	0	14.5	3.8	0	5.1	1.6	0
Southwinds	4	91.7	1.9	0	67.3	1.0	0	51.6	2.1	(1)	30.8	3.2	0	14.3	3.0	0	6.6	1.1	0
Stewart	12	86.4	2.3	0	67.6	3.0	0	50.5	2.7	0	29.0	2.3	0	11.1	1.6	0	4.3	1.0	0
Totten	5	80.3	1.9	0	60.1	1.9	(1)	44.7	2.8	(1)	24.3	2.9	0	9.6	2.9	0	4.7	2.3	0
Vanderburget	5	89.8	1.3	0	65.6	3.8	0	47.2	2.9	0	27.2	1.3	0	8.9	0.9	0	3.8	0.4	0
Summary	*54*	*87.8*	*2.5*	*0*	*66.9*	*3.2*	*5 (1)*	*47.9*	*3.4*	*(2)*	*28.8*	*2.9*	*0*	*12.4*	*2.5*	*0*	*4.5*	*1.2*	*0*
QUARRIES (22.4 mm)																			
Allied Chemical	47	85.2	3.6	0	65.6	5.6	0	41.7	5.2	2 (1)	21.8	3.2	1	13.6	2.0	0	9.7	1.8	12
King	7	88.8	2.0	0	64.3	3.7	0	42.3	3.4	0	21.1	1.6	0	12.3	3.5	0	7.2	0.6	0
Summary	*54*	*85.7*	*3.4*	*0*	*65.3*	*5.2*	*0*	*41.8*	*5.0*	*2 (1)*	*21.7*	*3.0*	*1*	*13.4*	*2.3*	*0*	*9.4*	*1.7*	*12*
QUARRIES (37.5 mm)																			
Allied Chemical	27	72.9	5.0	1	51.2	5.6	6 (1)	33.4	4.5	12 (1)	18.0	2.4	3	11.7	2.2	1	8.5	1.2	1

NC = Non Conforming Lots ( ) Indicates Non Conformance On Range

Fig. 6

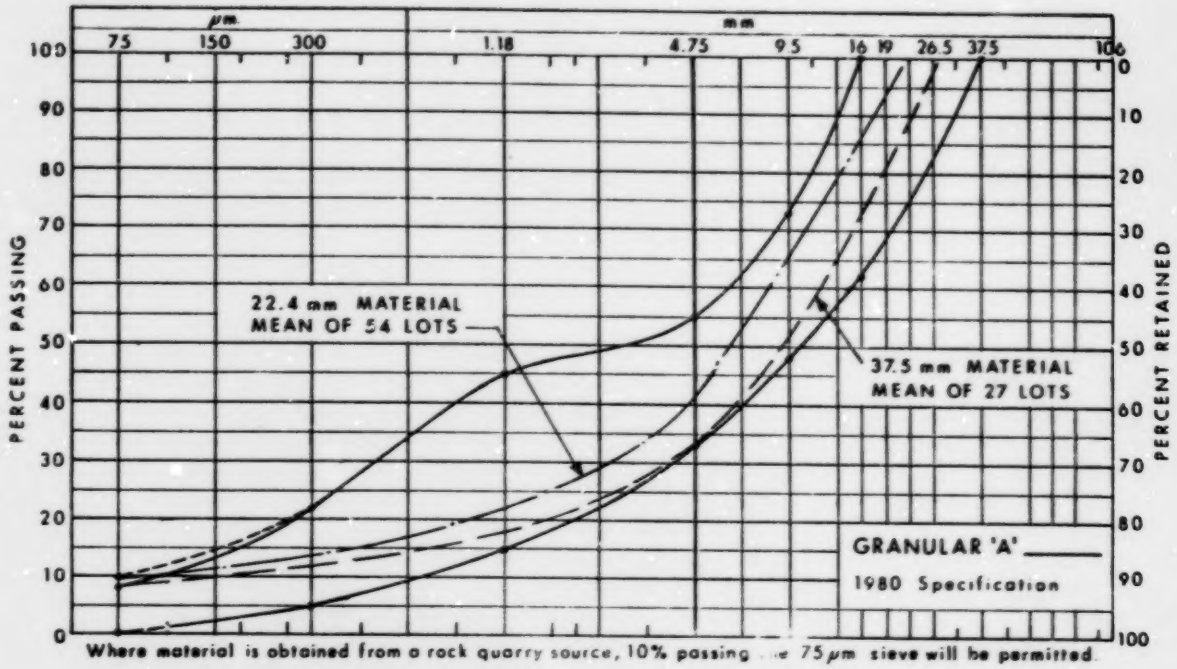


Fig. 7

COMPARISON OF 22.4 mm & 37.5 mm QUARRY MATERIAL
FROM ONE SOURCE IN SOUTHWESTERN REGION

4.2.2 Subbase Materials

Granular B: The Homes Pit with ten lots was the only source analysed, all lots conforming to specification.

Granular C: Kings Quarry was the one source analysed with all eight lots conforming to specification.

4.3 Eastern Region

4.3.1 Base Course Materials

Granular A: A total of eleven sources and some one hundred and thirty-eight lots were analysed. For each source the number of lots, the mean, the standard deviation and the number of non conforming lots are shown for each designated sieve. This data is presented in tabular form on Figure 8. The eleven sources were summarized in three separate groups.

Four sources produced 22.4 mm max. size, and two sources produced 37.5 mm max size material from pits, the remaining five sources produced 22.4 mm max, size material from quarries. Summary totals indicate the total number of lots, a weighted mean, a weighted average standard deviation and the total non conforming lots. Of the sixty lots analysed from pit sources only one lot was non conforming. Seventy-eight lots were analysed for quarry sources, three lots were considered as non conforming. All four non conforming lots were outside specification on gradation.

16 mm Crushed Type 'A': The Lyell Pit was the only source analysed with all five lots conforming to specification.

16 mm Crushed Type 'B': Four sources and a total of twenty-eight lots were analysed. The data is presented on Figure 9 and shows one non conforming lot on the 4.75 sieve.

4.3.2 Subbase Materials

Granular C: Four sources and a total of forty-four lots were analysed. This data is shown on Figure 10. A total of eight lots were considered to be non conforming, one on range with, two being outside on gradation and range on the 75 μm sieve. Most of the lots outside specification on gradation were out less than one percent.

SUMMARY OF GRANULAR 'A' SOURCES - 1980 CONSTRUCTION SEASON

EASTERN REGION

SOURCE (Min. of 4 lots)	LOT n	DESIGNATED SIEVES																	
		16.0 mm			9.5 mm			4.75 mm			1.18 mm			300 μm			75 μm		
		$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC
PITS (22.4 mm)																			
Hoffman	21	85.5	3.2	0	65.2	3.7	1	49.5	3.2	0	33.8	2.4	0	14.6	2.2	0	3.7	0.8	0
McCuaig	4	90.2	1.8	0	67.8	4.1	0	49.4	5.3	0	25.4	2.8	0	10.3	1.2	0	5.4	0.6	0
Sweeney	6	85.6	2.8	0	65.6	2.8	0	47.7	4.2	0	29.8	1.8	0	12.3	1.6	0	5.3	0.5	0
Wise	9	83.5	2.1	0	62.4	2.7	0	48.2	2.5	0	32.6	2.0	0	16.6	0.9	0	4.7	0.5	0
Summary	*40*	*85.5*	*2.8*	*0*	*64.9*	*3.4*	*1*	*48.9*	*3.5*	*0*	*32.1*	*2.3*	*0*	*14.3*	*1.6*	*0*	*4.3*	*0.7*	*0*
PITS (37.5 mm)																			
Chatson	12	70.9	2.3	0	60.0	2.3	0	50.9	2.1	0	37.1	2.2	0	15.3	2.2	0	3.8	1.0	0
Clement	8	70.6	4.4	0	57.6	2.9	0	47.5	2.0	0	34.1	1.7	0	12.2	2.5	0	2.0	1.0	0
Summary	*20*	*70.8*	*3.3*	*0*	*59.0*	*2.6*	*0*	*49.5*	*2.1*	*0*	*35.9*	*2.0*	*0*	*14.1*	*2.3*	*0*	*3.1*	*1.0*	*0*
QUARRIES (22.4 mm)																			
Francon	21	90.8	2.1	0	62.6	4.8	0	38.2	2.9	0	17.7	1.5	0	8.8	1.1	0	4.9	0.5	0
McLeod	30	93.6	2.0	0	68.5	2.8	1	42.8	3.0	0	17.0	1.3	0	7.7	0.7	0	3.9	0.5	0
Smith	7	89.2	2.0	0	67.9	2.3	0	44.3	2.6	0	20.1	2.3	0	9.9	1.2	0	5.4	0.7	0
Westbrook	4	88.1	2.7	0	69.1	3.8	0	43.9	1.9	0	18.8	1.8	0	8.5	0.7	0	5.0	0.5	0
Wings	16	91.2	1.8	0	65.5	4.4	0	40.1	3.9	1	20.3	2.4	1	12.0	1.6	0	6.9	1.0	0
Summary	*78*	*91.7*	*2.0*	*0*	*66.3*	*3.8*	*1*	*41.2*	*3.1*	*1*	*18.2*	*1.8*	*1*	*9.1*	*1.1*	*0*	*5.0*	*0.7*	*0*

NC = Non Conforming Lots ( ) Indicates Non Conformance On Range

Fig. 8

SUMMARY OF 16mm CR. TYPE 'B' SOURCES - 1980 CONSTRUCTION SEASON — EASTERN REGION

SOURCE (Min of 4 lots)	LOT n	DESIGNATED SIEVES																					
		13.2 mm			9.5 mm			4.75 mm			1.18 mm			300 µm			150 µm			75 µm		
		$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC
Pennell	13	90.3	1.9	0	66.9	5.7	0	37.7	4.3	0	16.7	3.0	0	7.4	0.3	0	4.9	0.6	0	3.3	1.0	0
Rentz	6	90.6	2.8	0	70.6	3.3	0	44.9	2.6	0	27.8	2.3	0	11.2	1.2	0	6.8	1.0	0	3.8	0.4	0
Thompson	4	90.6	1.9	0	67.4	3.3	0	45.0	1.5	0	26.7	0.6	0	8.3	0.6	0	4.2	0.3	0	3.0	0.5	0
York	5	92.8	1.5	0	72.1	4.6	0	48.2	5.2	1	27.3	1.9	0	10.8	0.7	0	6.5	0.4	0	4.2	0.3	0
Summary	*28*	*90.9*	*2.2*	*0*	*68.7*	*4.8*	*0*	*42.2*	*3.9*	*1*	*22.4*	*2.5*	*0*	*9.0*	*0.9*	*0*	*5.5*	*0.7*	*0*	*3.5*	*0.7*	*0*

NC = Non Conforming Lots

Fig. 9

SUMMARY OF GRANULAR 'C' SOURCES - 1980 CONSTRUCTION SEASON — EASTERN REGION

SOURCE (Min of 4 lots)	LOT n	DESIGNATED SIEVES																	
		26.5 mm			4.75 mm			1.18 mm			300 µm			150 µm			75 µm		
		$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC
Cerss	4	90.9	2.3	0	80.7	5.5	0	65.4	8.1	0	2 .5	6.0	0	5.8	2.3	1	2.2	0.8	0
Hugll	24	100.0	0	0	99.5	1.7	0	97.1	3.5	0	56.3	11.6	0	18.2	5.6	0	6.2	2.6	3 (1)
Taylor	11	95.7	2.0	0	89.3	4.2	0	80.4	8.7	0	45.9	10.4	0	14.7	4.0	0	3.6	1.5	0
York	5	81.8	13.4	0	57.4	24.9	0	32.1	15.4	0	9.8	7.7	0	6.6	5.3	2	4.3	3.8	1
Summary	*44*	*96.0*	*4.7*	*0*	*90.5*	*8.9*	*0*	*82.7*	*7.6*	*0*	*46.2*	*10.5*	*0*	*14.9*	*5.0*	*3*	*5.0*	*2.4*	*4 (1)*

NC = Non Conforming Lots ( ) Indicates Non Conformance On Range

Fig. 10

4.4 Northern Region

4.4.1 Base Course Materials

Granular A: Some nineteen sources and a total of one hundred and forty-one lots were analysed. For each source the number of lots, the mean, the standard deviation and the number of non conforming lots are shown for each designated sieve. This data is presented in tabular form on Figure 11.

The nineteen sources have been summarized in three groups with fifteen of the sources producing 22.4 mm max. size pit material, three sources producing 37.5 mm max. size pit material and one quarry source producing 22.4 mm max. size material. Summary totals indicate the total number of lots, a weighted mean, a weighted average standard deviation and the total non conforming lots for each sieve.

Of the one hundred and forty-one lots analysed, thirteen were considered non conforming on gradation and six were outside specification on the range. Most of the non conforming lots were only one or two percent outside specification, with fifteen of the lots having less than five adjustment points (Appendix E).

16 mm Crushed Type 'A': Four sources and a total of thirty lots were analysed for this material. Five lots were non conforming, all on the 4.75 mm sieve, ranging from 0.4% to 4.0% outside specifications. This data is presented on Figure 12.

16 mm Crushed Type 'B': The pagnutti Pit was the one source analysed, all six lots conforming to specifications.

4.4.2 Subbase Materials

Granular C: Four sources and a total of twenty-five lots were analysed. Five lots were considered non conforming, all five lots being 1% or less outside specifications. This data is presented on Figure 13.

SUMMARY OF GRANULAR 'A' SOURCES - 1980 CONSTRUCTION SEASON

NORTHERN REGION

SOURCE (Min. of 4 lots)	LOT n	DESIGNATED SIEVES																	
		16.0 mm			9.5 mm			4.75 mm			1.18 mm			300 μm			75 μm		
		$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC	$\bar{x}$	σ	NC
PITS (22.4 mm)																			
Friar	12	83.6	4.2	0	66.3	3.5	0	46.4	5.1	0	29.3	3.6	0	11.2	1.8	0	2.2	0.4	0
Inco	10	89.7	3.3	0	68.3	1.8	0	51.7	2.2	0	30.9	2.4	0	15.4	1.4	0	6.2	0.9	0
Jones	4	77.6	2.9	0	60.0	7.1	0	46.6	2.6	0	34.2	2.6	0	16.7	1.0	0	3.7	1.0	0
M.T.C. #1472	4	84.5	3.7	0	64.7	0.5	0	46.3	2.2	0	20.2	3.1	0	7.1	2.5	0	2.6	1.1	0
M.T.C. #7, 79-73	4	82.5	2.0	0	-	-	-	45.0	5.0	(1)	30.9	5.5	0	16.3	4.7	0	2.8	0.5	0
Norton	5	83.0	1.9	0	-	-	-	48.4	3.3	0	29.6	4.1	0	11.1	1.5	0	2.0	0.2	0
Pagnutti	10	89.0	3.5	0	64.7	5.6	2	49.6	3.3	1	24.0	3.5	0	9.2	2.5	0	3.0	1.6	0
Pakesley	5	83.8	1.1	0	64.8	3.1	0	49.1	3.4	0	30.6	4.1	(1)	13.8	2.2	0	3.9	0.5	0
M.T.C. #2, 79-53	5	86.2	1.7	0	64.8	4.0	0	47.7	3.6	0	32.2	3.9	0	11.8	1.3	0	2.3	0.7	0
M.T.C. #1304	12	87.9	2.3	0	65.7	2.2	0	49.2	3.9	0	29.3	3.4	0	13.7	2.2	0	5.0	1.2	(2)
M.T.C. #1303	6	85.4	2.0	0	64.2	1.7	0	50.2	0.8	0	36.1	4.8	0	14.5	1.5	0	4.6	0.6	0
M.T.C. #1293	5	86.2	1.9	0	69.2	2.2	0	56.2	2.8	3	38.7	3.7	0	19.8	3.1	1	4.0	0.9	0
M.T.C. #30, 79-53	20	82.4	2.5	0	61.6	3.4	0	47.3	4.5	1 (2)	35.9	2.8	0	16.2	2.9	0	2.9	0.6	0
Poutanen	5	85.5	2.0	0	65.8	2.5	0	51.0	1.7	0	34.3	2.1	0	19.4	1.6	0	7.0	0.9	1
Queenston #4	4	84.8	1.7	0	-	-	-	51.7	3.6	1	27.0	1.4	0	4.5	0.7	2	1.6	0.2	0
Summary	*111*	*86.1*	*2.8*	*0*	*64.7*	*3.5*	*2*	*48.9*	*3.7*	*6 (3)*	*31.2*	*3.4*	*(1)*	*13.6*	*2.3*	*3*	*3.6*	*0.9*	*1 (2)*
PITS (37.5 mm)																			
McCarthy	9	70.9	4.0	0	55.0	3.8	0	42.8	3.4	0	27.1	2.7	0	10.0	1.6	0	3.1	0.8	0
M.T.C. #4, 80-203	9	76.2	1.9	0	64.8	1.3	0	52.4	1.3		24.8	2.2	0	6.9	0.7	0	2.3	0.4	0
Pagnutti	5	78.7	1.5	0	58.6	3.9	0	42.6	3.4	(	21.8	3.6	0	7.7	1.2	0	2.2	0.4	0
Summary	*23*	*74.7*	*2.9*	*0*	*59.6*	*3.1*	*0*	*46.5*	*2.8*	*0*	*25.0*	*2.8*	*0*	*8.3*	*1.2*	*0*	*2.6*	*0.6*	*0*
QUARRIES (22.4 mm)																			
Cook	7	98.3	1.2	0	68.3	1.5	0	38.8	2.2	0	15.2	1.3	2	8.1	1.0	0	5.2	0.9	0

NC = Non Conforming Lots ( ) Indicates Non Conformance On Range

Fig. 11

SUMMARY OF 16mm CR. TYPE 'A' SOURCES - 1980 CONSTRUCTION SEASON

NORTHERN REGION

SOURCE (Min of 4 lots)	LOT n	DESIGNATED SIEVES																					
		13.2 mm			9.5 mm			4.75 mm			1.18 mm			300 µm			150 µm			75 µm		
		$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC
Blakely	15	84.5	1.7	0	66.0	2.3	0	48.3	1.6	0	32.3	1.7	0	13.4	2.6	0	5.5	1.2	0	2.5	0.6	0
McAllister	6	89.1	1.5	0	70.0	2.0	0	49.5	1.4	2	30.2	0.9	0	13.6	2.2	0	5.4	0.6	0	2.0	0.3	0
McCarthy	4	-	-	-	70.7	4.5	0	49.3	5.7	3	31.6	2.6	0	14.0	0.3	0	8.3	0.3	0	4.5	0.3	0
M.T.C. #1, 80-202	5	88.2	2.3	0	69.1	3.6	0	43.3	3.4	0	21.4	2.6	0	11.3	4.0	0	5.2	0.7	0	3.1	0.5	0
Summary	*30*	*86.3*	*1.8*	*0*	*68.0*	*2.9*	*0*	*47.8*	*2.8*	*5*	*30.0*	*1.9*	*0*	*13.2*	*2.7*	*0*	*5.8*	*0.9*	*0*	*2.8*	*0.5*	*0*

NC = Non Conforming Lots

Fig. 12

SUMMARY OF GRANULAR 'C' SOURCES - 1980 CONSTRUCTION SEASON

NORTHERN REGION

SOURCE (Min. of 4 lots)	LOT n	DESIGNATED SIEVES																	
		26.5 mm			4.75 mm			1.18 mm			300 µm			150 µm			75 µm		
		$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC
C & J	4	93.3	3.7	0	67.2	6.8	0	46.6	9.2	0	13.8	1.0	0	3.7	0.2	3	1.1	0.1	0
Inco Pit #2	7	100.0	0	0	82.0	5.2	0	64.6	5.9	0	31.4	6.5	0	14.2	4.9	0	6.8	2.8	1
Lammi	6	100.0	0	0	93.4	9.7	0	78.0	6.3	0	41.2	10.6	0	16.8	6.7	0	7.2	2.8	(1)
H.N.R.	8	100.0	0	0	95.4	2.7	0	76.1	3.2	0	26.9	4.8	0	9.1	2.2	0	3.4	1.2	0
Summary	*25*	*98.9*	*1.5*	*0*	*86.7*	*6.3*	*0*	*68.6*	*6.0*	*0*	*29.5*	*6.8*	*0*	*11.5*	*4.4*	*3*	*4.9*	*2.2*	*1 (1)*

NC = Non Conforming Lots ( ) Indicates Non Conformance On Range

Fig. 13

4.5 Northwestern Region

4.5.1 Base Course Materials

Granular A: Some twelve sources and a total of one hundred and twenty-one lots were analysed. For each source the number of lots, the mean, the standard deviation and the number of non conforming lots are shown for each designated sieve. This data is presented in tabular form on Figure 14. The twelve sources were summarized in two groups, ten sources producing 22.4 mm max. size pit material and two sources producing 37.5 mm max. size pit material. Summary totals indicate the total number of lots, a weighted mean, a weighted average standard deviation and the total number of non conforming lots for each designated sieve.

Of the one hundred and twenty-one lots analysed, seven lots were considered non conforming with two lots being outside specifications on more than one sieve size. Six of the seven lots had less than five adjustment (Appendix E) points and would be considered borderline.

16 mm Crushed Type 'A': One source analysed, Chapel Pit with twenty-two lots, seventeen lots having a full gradation and five lots having a coarse gradation. Several lots for this source had only one test (sublot). These lots were not included in the analysis for statistical purposes. All lots analysed conformed to specifications.

16 mm Crushed Type 'B': One unknown source with four lots was analysed. One lot was outside specification by 0.7% on the 4.75 mm sieve.

4.5.2 Subbase Materials

Granular C: Two sources were analysed, MNR Pit, Cont. 80-220 having four lots, with two lots out of specification by less than 1% on the 150 µm sieve and MTC Pit Number 3, Cont. 79-401 having five lots, with one lot outside the acceptable range on the 75 µm.

SUMMARY OF GRANULAR 'A' SOURCES - 1980 CONSTRUCTION SEASON

NORTHWESTERN REGION

SOURCE (Min. of 4 lots)	LOT n	DESIGNATED SIEVES																	
		16.0 mm			9.5 mm			4.75 mm			1.18 mm			300 μm			75 μm		
		$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC	$\bar{X}$	σ	NC
PITS (22.4 mm)																			
Deadman	10	83.4	4.3	0	62.2	4.2	0	44.8	2.8	0	24.6	2.0	0	7.9	0.5	0	2.2	0.3	0
Dixie Lake	9	79.3	2.4	0	-	-	-	42.8	4.4	0	22.5	6.5	1	6.3	1.8	1	2.3	1.9	0
Eagle	25	89.2	1.6	0	68.7	2.1	0	52.2	2.0	0	30.4	4.4	0	13.8	3.2	(1)	5.2	1.1	0
Hasden Mine	17	83.4	2.8	0	-	-	-	44.6	4.8	0	28.4	5.5	0	12.3	3.6	1	4.4	1.0	0
Phillips Creek	13	75.8	2.1	0	58.1	2.3	0	47.4	2.4	0	32.2	2.2	0	17.0	2.1	1	6.2	1.2	1
M.T.C. #2A-6	7	90.3	1.5	0	68.0	2.2	0	50.7	1.8	0	30.2	2.8	0	9.3	1.3	0	2.3	0.7	0
M.T.C. #1F-28	15	83.5	2.6	0	-	-	-	50.5	3.0	2	31.4	2.9	0	10.7	2.0	0	2.1	0.9	0
M.T.C. (Crystal L)	5	85.4	3.9	0	66.3	5.0	0	50.7	4.4	1	28.9	2.9	0	10.4	1.5	0	1.8	0.7	0
M.T.C. #128	5	80.1	1.4	0	60.4	2.0	0	49.1	2.5	0	37.1	3.5	0	13.3	2.9	0	2.1	0.4	0
Scattergood	5	82.6	4.3	0	65.8	5.5	0	48.1	5.2	0	22.1	1.0	0	9.1	1.0	0	3.0	0.4	0
Summary	*111*	*83.8*	*2.7*	*0*	*64.8*	*3.1*	*0*	*48.3*	*3.3*	*3*	*29.1*	*4.0*	*1*	*11.7*	*2.6*	*3 (1)*	*3.7*	*1.0*	*1*
PITS (37.5 mm)																			
M.T.C. #128	4	66.0	2.4	0	55.0	2.5	0	48.8	2.7	0	42.1	2.6	0	13.6	1.2	0	2.2	0.2	0
Wade	6	71.0	2.9	0	57.0	2.6	0	45.8	2.9	0	33.6	2.8	0	16.5	1.3	0	3.3	0.4	0
Summary	*10*	*69.0*	*2.7*	*0*	*56.2*	*2.6*	*0*	*47.0*	*2.8*	*0*	*37.0*	*2.7*	*0*	*15.3*	*1.3*	*0*	*2.9*	*0.3*	*0*

NC = Non Conforming Lots ( ) Indicates Non Conformance On Range

Fig. 14

4.6 Provincial Summaries

Provincial summaries and analysis were carried out on granular base and subbase materials. Lots indicating removal or rejection were omitted. All other data received were analysed using lot values. This was accomplished by the use of frequency tables.

Histograms have been developed for some of the summaries to graphically illustrate the dispersion of lot values on various sieves.

Acceptance of lots based on the range of individual tests within a lot was included in the 1980 guidelines for granular materials. As this was a new concept, there was some concern and doubt about the range method. A Summary of the 1980 Range analysis for granular 'A' is presented in tabular form on Figure 15.

SIEVE	1980 RANGE DATA			1980 GUIDELINES		
	Nº OF LOTS	$\bar{X}$	σ	ACCEPT. RANGE	LOTS OUTSIDE	
					Nº	%
16.0 mm	943	6.1	3.9	38	0	0
9.5 mm	839	9.4	5.1	25	5	0.6
4.75 mm	941	8.8	4.9	22	11	1.2
1.18 mm	939	7.0	4.2	30	1	0.1
300 µm	939	4.2	2.6	17	1	0.1
75 µm	938	2.1	1.5	8	4	0.4

Fig. 15

Summary of 1980 Range Analysis for Granular 'A'

A review of the data on Figure 15 indicates that the average range for each sieve was less than half the acceptable range, and the total number of non conforming lots for the six designated sieves was 22 for the entire province. Statistical concepts also indicate that more than 99% of all data was well within the acceptance guidelines for range.

4.6.1 Base Course Materials

Granular A: Pit material, 22.4 mm maximum size was produced in all regions and represents six hundred and sixty-nine lots, approximately 70% of production. Histograms have been developed for each designated sieve size and show number of lots, average percent passing, standard deviation and percent of lot values within specifications using statistical concepts. This data is presented on Figures 16 a to 16 f.

Granular A: Pit material, 37.5 mm maximum size was produced in all regions except southwestern, a total of seventy-one lots, represetning 7% of total granular 'A' production. Of the seventy-one lots, one lot was non conforming on the 1.18 mm sieve being outside specification by less than 1%.

Granular A: Quarry Material, 22.4 mm maximum size was produced in all regions except northwestern, a total of two hundred and two lots, representing 20% of granular 'A' production. Histograms have been developed for each designated sieve size, showing number of lots, average percent passing, standard deviation and percent of lot values within specifications using statistical concepts. This data is presented on Figures 17 a to 17 f.

Granular A: Quarry Material, 37.5 mm maximum size was produced in one source in southwestern region, with twenty-seven lots being analysed. This source produced 22.4 mm maximum size and as well, is the main supplier of granular 'A' for this region. This source had a problem meeting specifications with approximately 50% of the lots being non conforming on the coarse side of the 4.75 mm sieve.

16 mm Crushed Type 'A' and Type 'B': This material was produced in all regions except Central Region. A total of one hundred and forty-one lots of both types of material was analysed. Seventeen lots were considered as non conforming, fifteen being outside specifications on the fine side of the 4.75 mm sieve.

4.6.2 Subbase Materials

Granular B: Eighty-one lots were analysed, sixty-one lots from Central Region sources and thirteen lots from two sources in southwest region. Four lots were considered as non conforming, all less than 1% outside specifications on the coarse side of the 300 µm sieve.

Granular C: Material was produced in all regions with three hundred and seventeen lots being analyzed. Histograms have been developed for each designated sieve size, showing number of lots, average percent passing, standard deviation and the percent of lot values within speficiation using statistical concepts. This data is presented on Figures 18 a to 18 f. Twenty-five lots were considered as non conforming for gradation and eight lots did not meet the range specification. All non conforming lots were on the 75 µm and 150 µm sieve sizes. 75% of non conforming lots had less than five adjustment points.

Granular D: No results were received for this material during 1980.

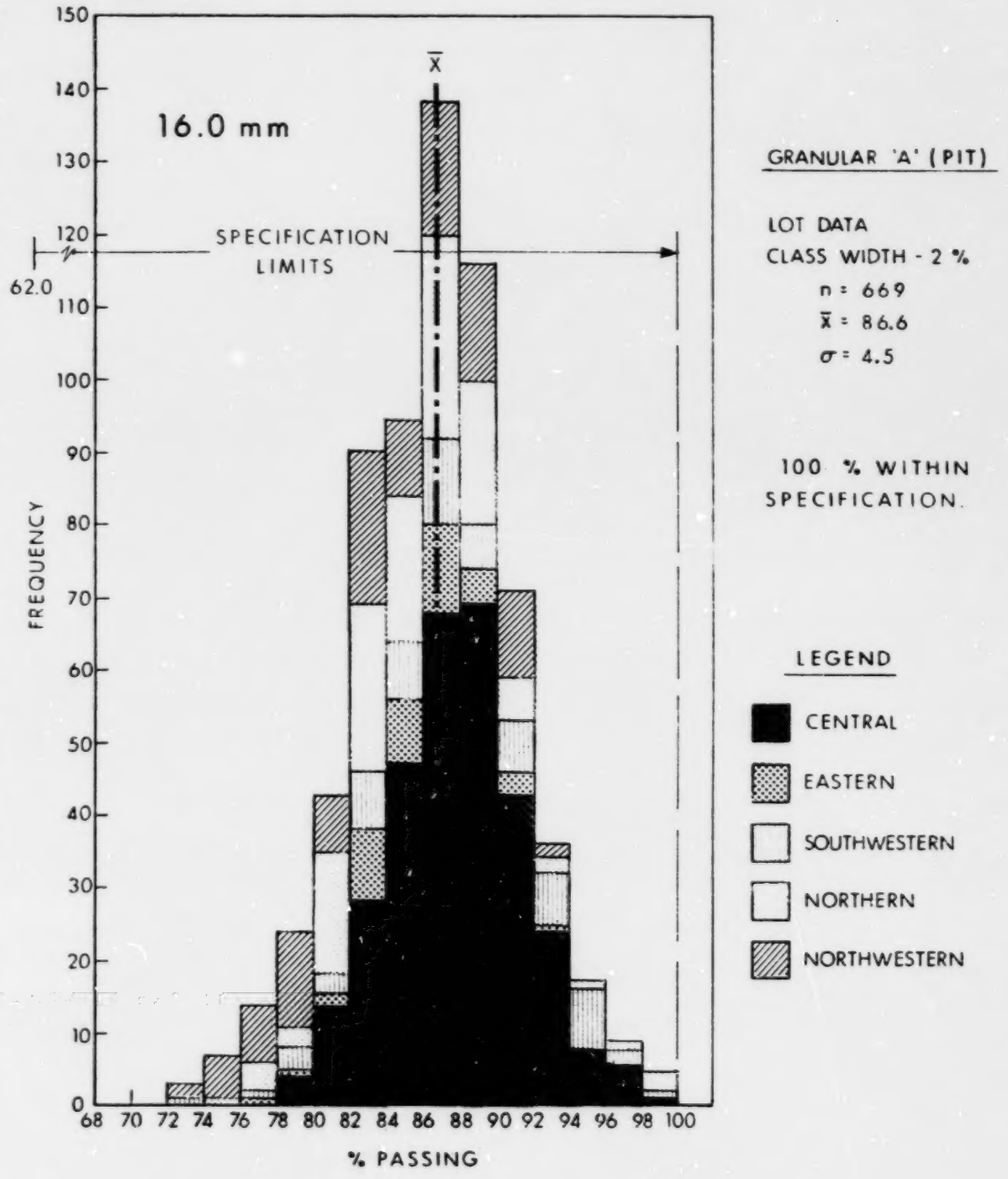
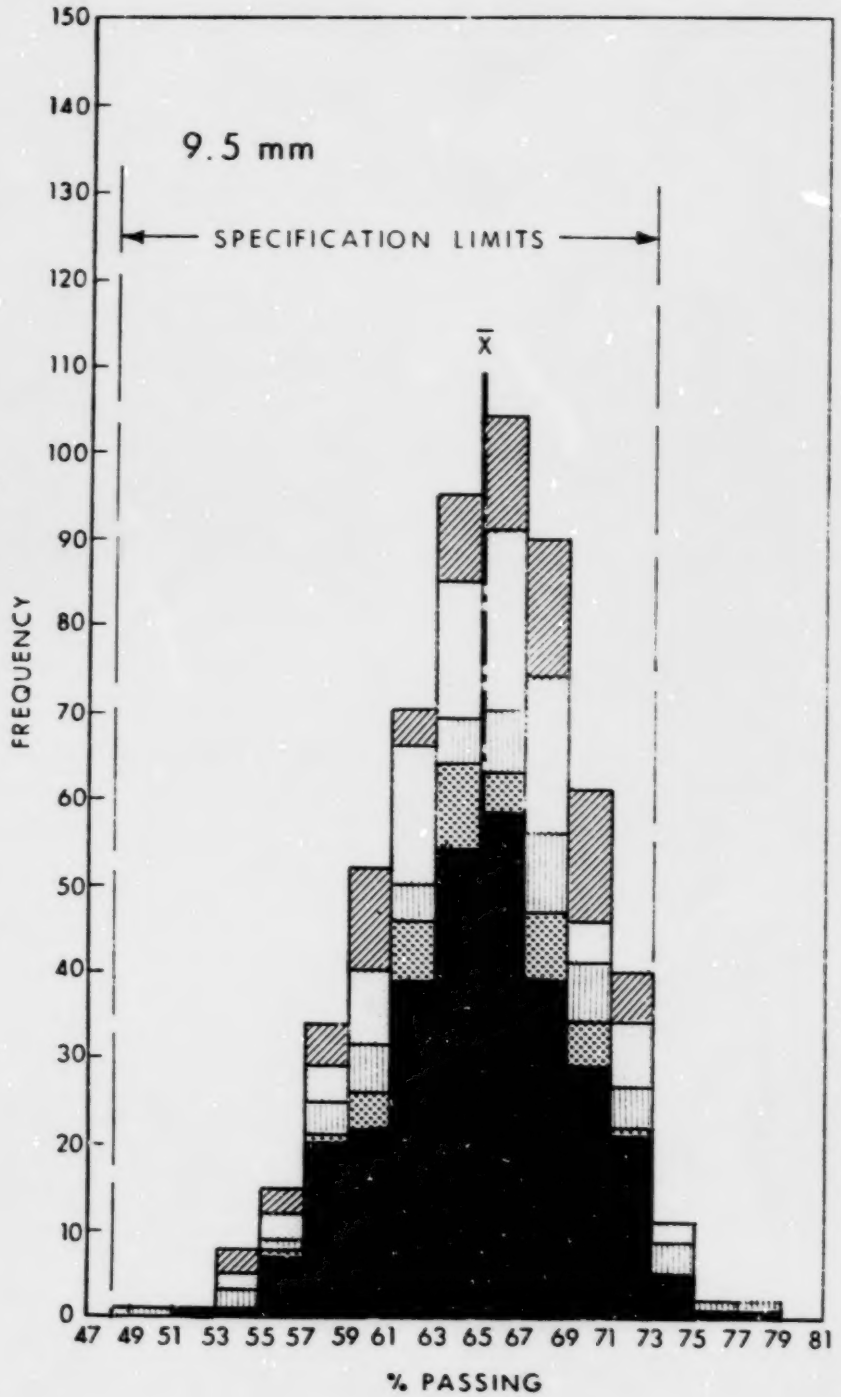

16.0 mm
$\bar{X}$
SPECIFICATION LIMITS
62.0
FREQUENCY
% PASSING
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100
GRANULAR 'A' (PIT)
LOT DATA
CLASS WIDTH - 2 %
n = 669
$\bar{X}$ = 86.6
σ = 4.5
100 % WITHIN SPECIFICATION.
LEGEND
CENTRAL
EASTERN
SOUTHWESTERN
NORTHERN
NORTHWESTERN

Fig. 16 a



GRANULAR 'A' (PIT)

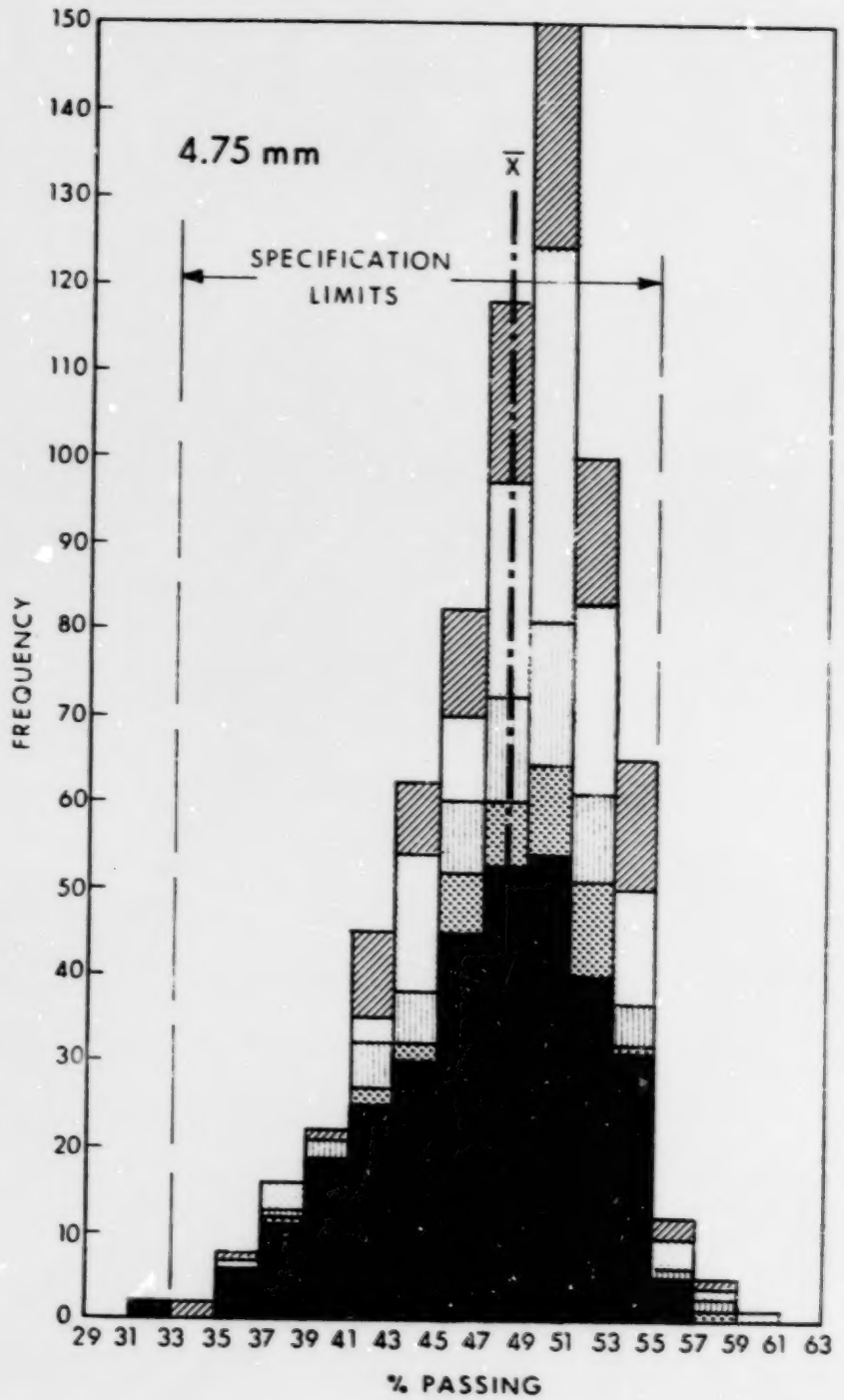
LOT DATA
CLASS WIDTH - 2 %
n = 587
$\bar{X}$ = 65.1
σ = 4.6

95.7 % WITHIN SPECIFICATION

LEGEND

- CENTRAL
- EASTERN
- SOUTHWESTERN
- NORTHERN
- NORTHWESTERN

Fig. 16 b



GRANULAR 'A' (PIT)

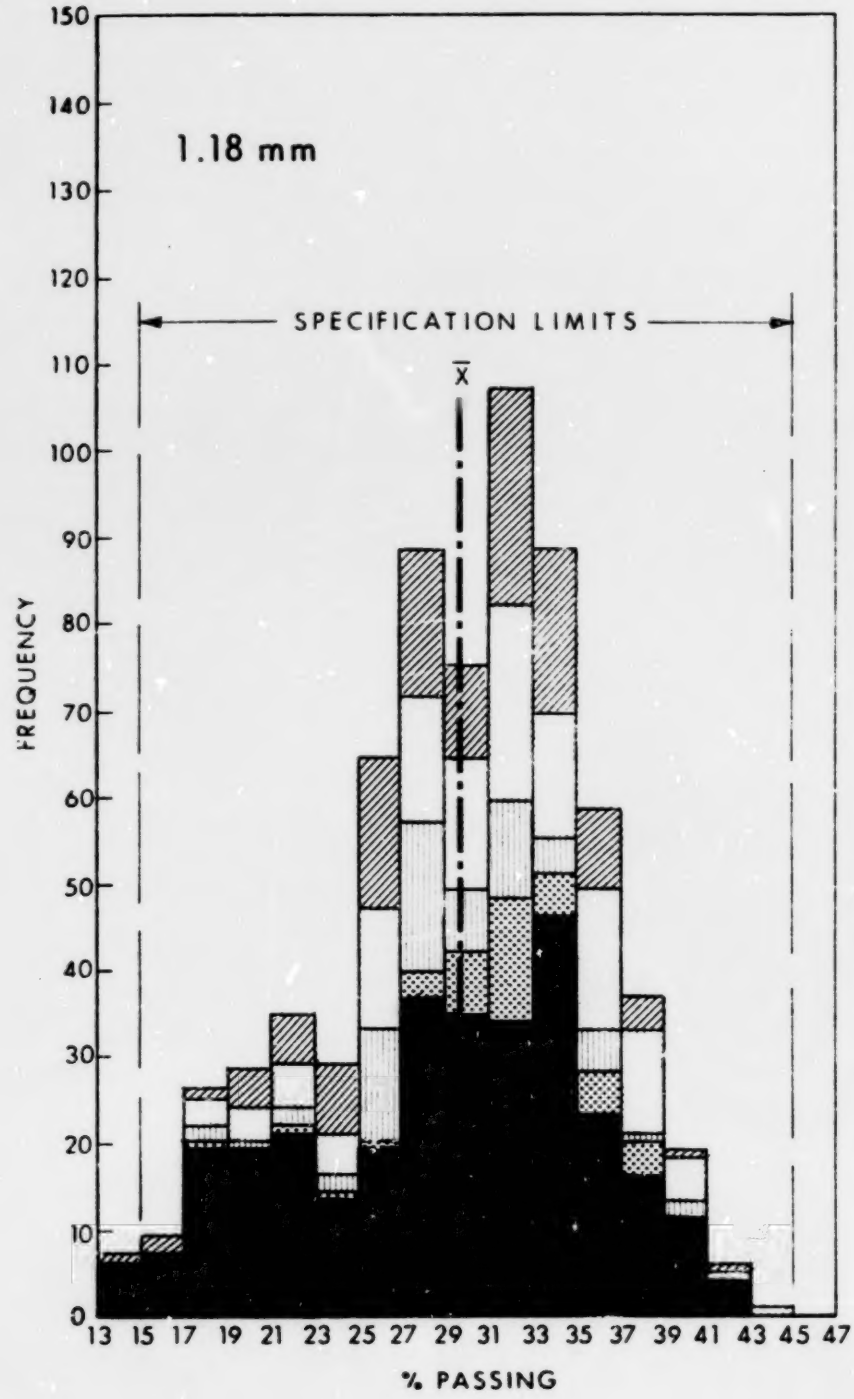
LOT DATA
CLASS WIDTH - 2 %
n = 679
$\bar{x}$ = 48.1
σ = 4.4

94.2 % WITHIN SPECIFICATION.

LEGEND

- CENTRAL
- EASTERN
- SOUTHWESTERN
- NORTHERN
- NORTHWESTERN

Fig. 16 c



GRANULAR 'A' (PIT)

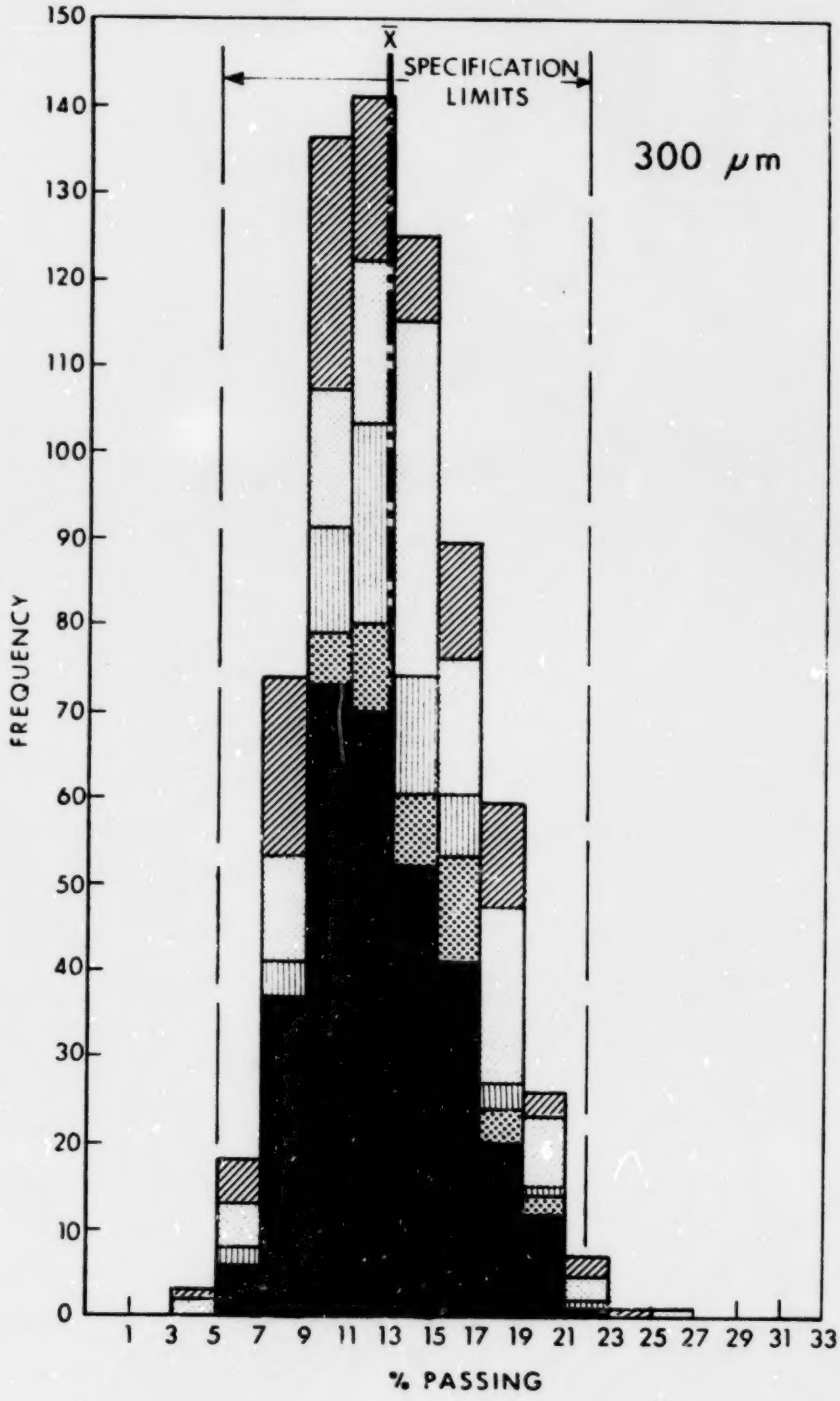
LOT DATA
CLASS WIDTH - 2 %
n = 677
$\bar{X}$ = 29.7
σ = 6.0

98.8 % WITHIN SPECIFICATION.

LEGEND

- CENTRAL
- EASTERN
- SOUTHWESTERN
- NORTHERN
- NORTHWESTERN

Fig. 16 d



GRANULAR 'A' (PIT)

LOT DATA
CLASS WIDTH - 2 %
n = 681
$\bar{X}$ = 12.8
σ = 3.6

98.0 % WITHIN SPECIFICATION.

LEGEND

- CENTRAL
- EASTERN
- SOUTHWESTERN
- NORTHERN
- NORTHWESTERN

Fig. 16 e

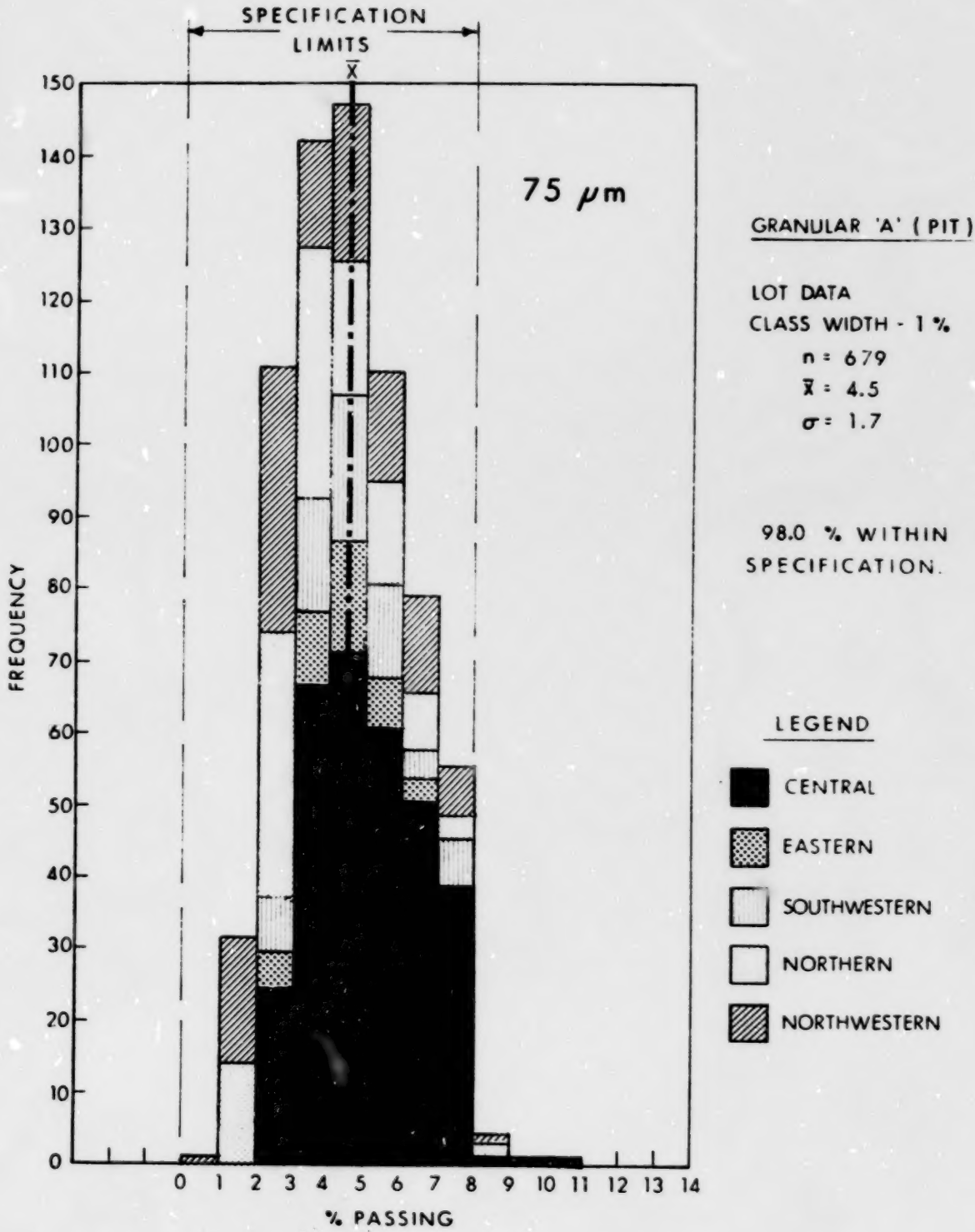
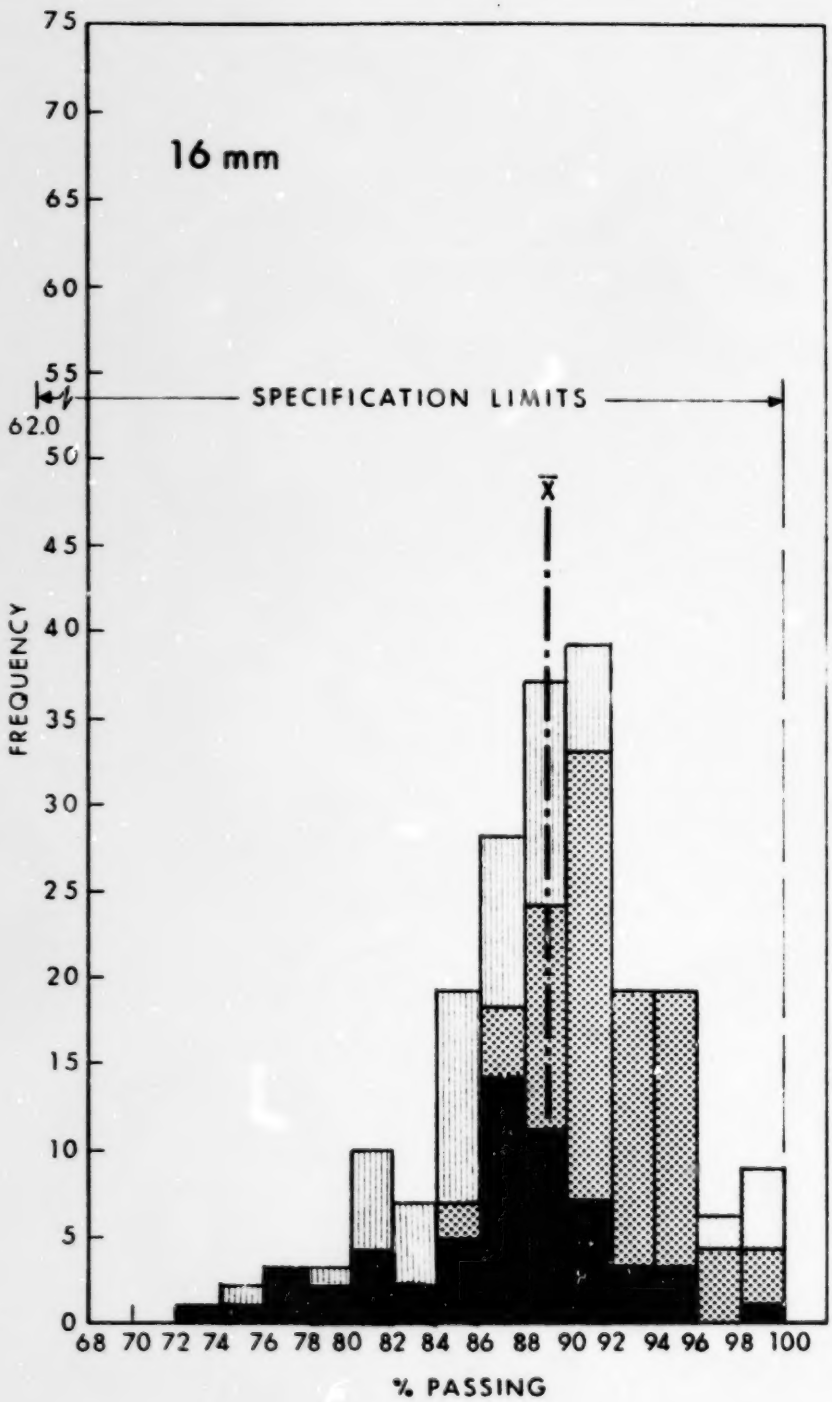

SPECIFICATION
LIMITS
$\bar{X}$
75 μm
FREQUENCY
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
% PASSING
GRANULAR 'A' (PIT)
LOT DATA
CLASS WIDTH - 1 %
n = 679
$\bar{X}$ = 4.5
σ = 1.7
98.0 % WITHIN
SPECIFICATION.
LEGEND
CENTRAL
EASTERN
SOUTHWESTERN
NORTHERN
NORTHWESTERN

Fig. 16 f



GRANULAR 'A' (QUARRY)

LOT DATA
CLASS WIDTH - 2 %
n = 202
$\bar{X}$ = 89.2
σ = 5.0

100 % WITHIN SPECIFICATION.

LEGEND

- CENTRAL
- EASTERN
- SOUTHWESTERN
- NORTHERN
- NORTHWESTERN

Fig. 17 a

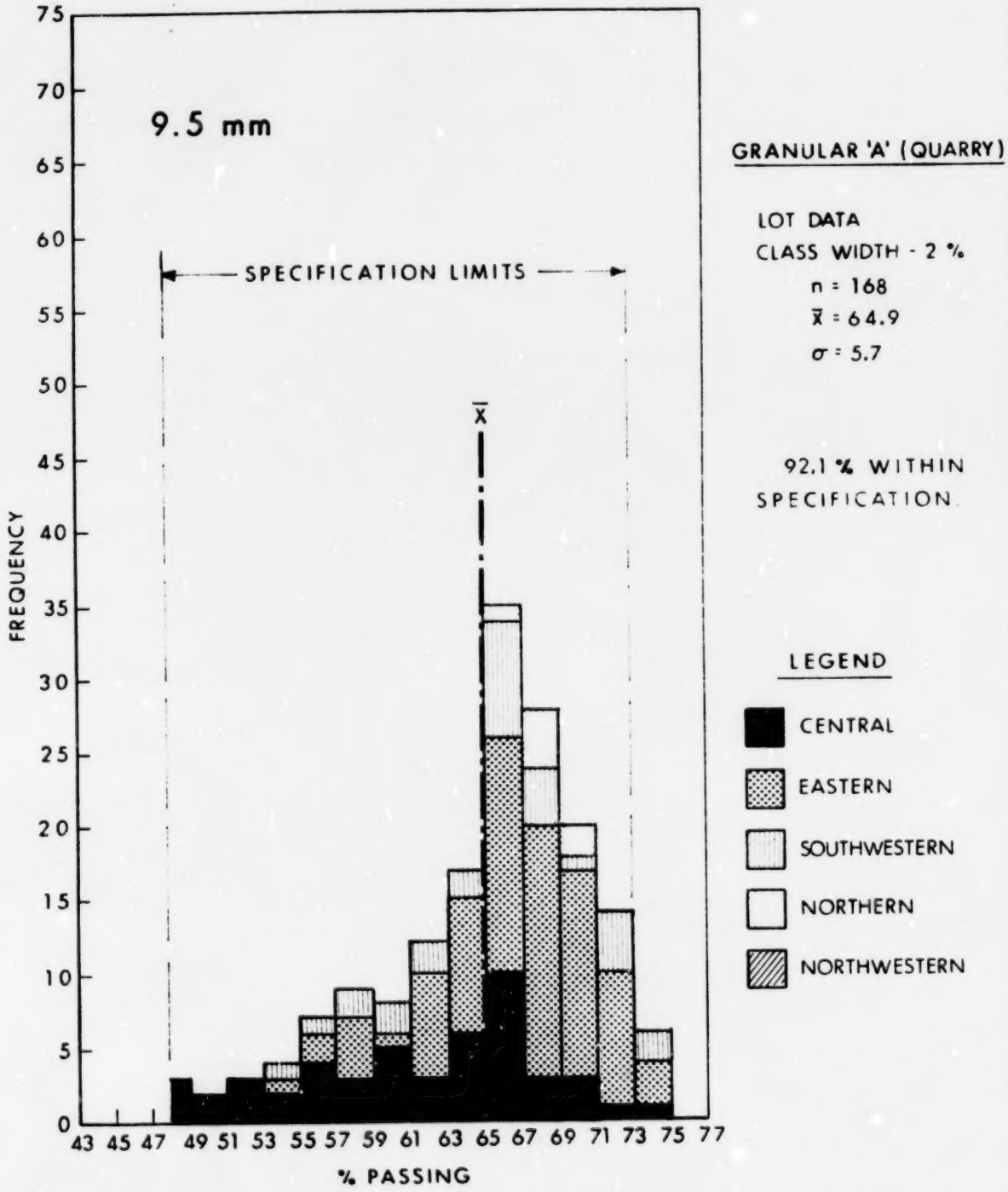
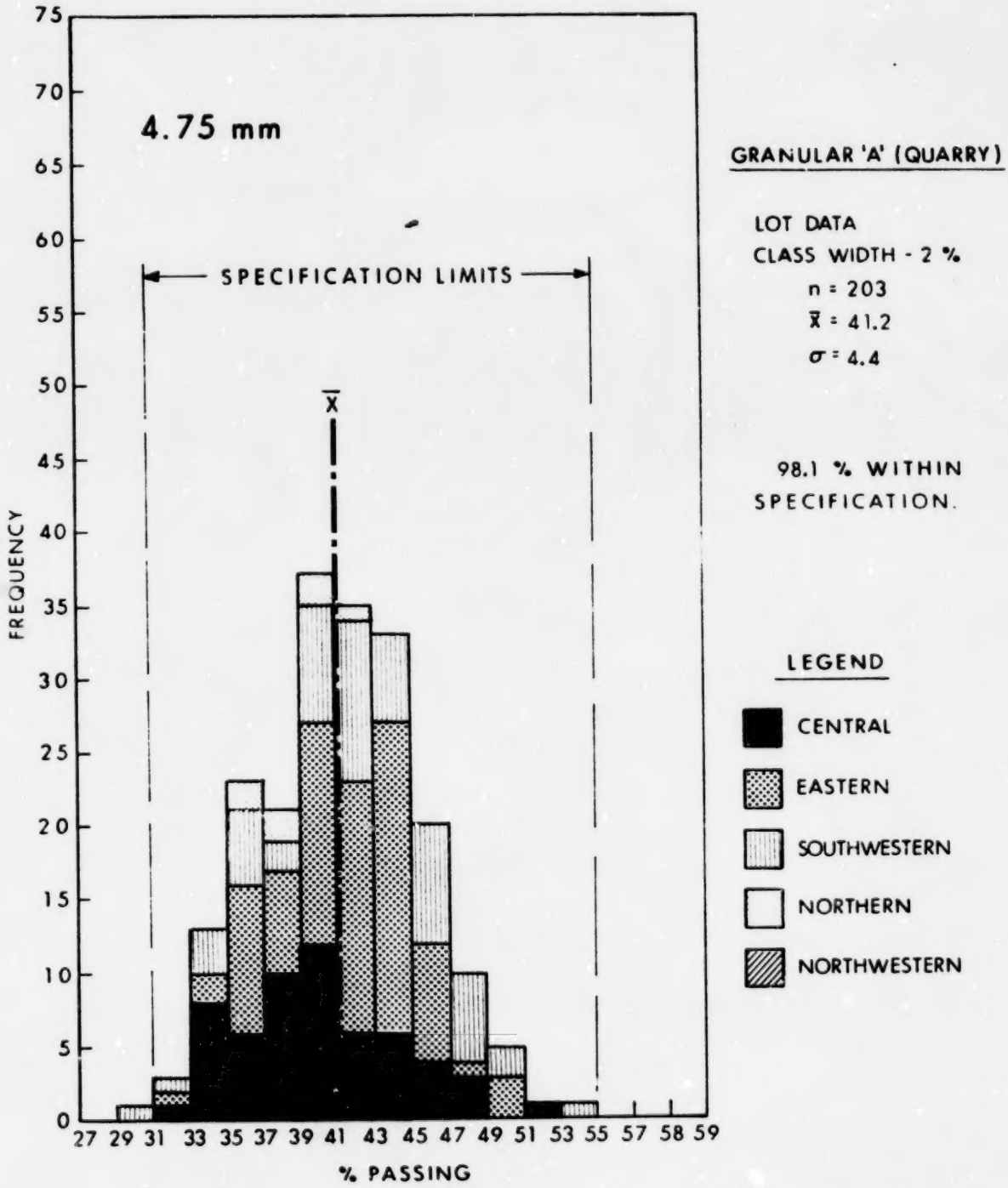

9.5 mm
SPECIFICATION LIMITS
FREQUENCY
% PASSING
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77
GRANULAR 'A' (QUARRY)
LOT DATA
CLASS WIDTH - 2 %
n = 168
x̄ = 64.9
σ = 5.7
92.1 % WITHIN SPECIFICATION
LEGEND
CENTRAL
EASTERN
SOUTHWESTERN
NORTHERN
NORTHWESTERN

Fig. 17 b



GRANULAR 'A' (QUARRY)

LOT DATA
CLASS WIDTH - 2 %
n = 203
$\bar{X}$ = 41.2
σ = 4.4

98.1 % WITHIN SPECIFICATION.

LEGEND

- CENTRAL
- EASTERN
- SOUTHWESTERN
- NORTHERN
- NORTHWESTERN

Fig. 17 c

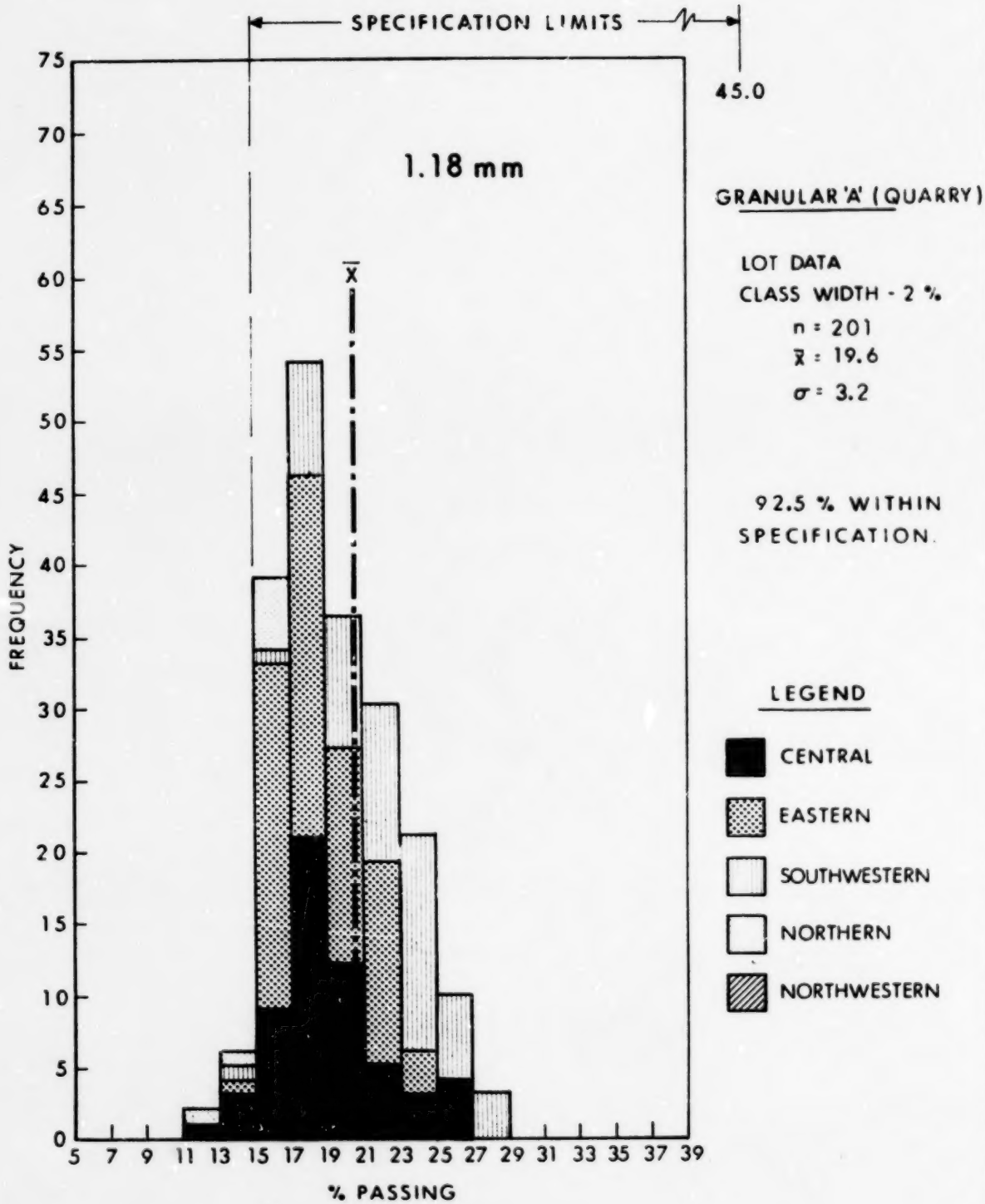

SPECIFICATION LIMITS
45.0
1.18 mm
GRANULAR 'A' (QUARRY)
LOT DATA
CLASS WIDTH - 2 %
n = 201
$\bar{x}$ = 19.6
σ = 3.2
92.5 % WITHIN SPECIFICATION.
LEGEND
CENTRAL
EASTERN
SOUTHWESTERN
NORTHERN
NORTHWESTERN
FREQUENCY
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39
% PASSING

Fig. 17 d

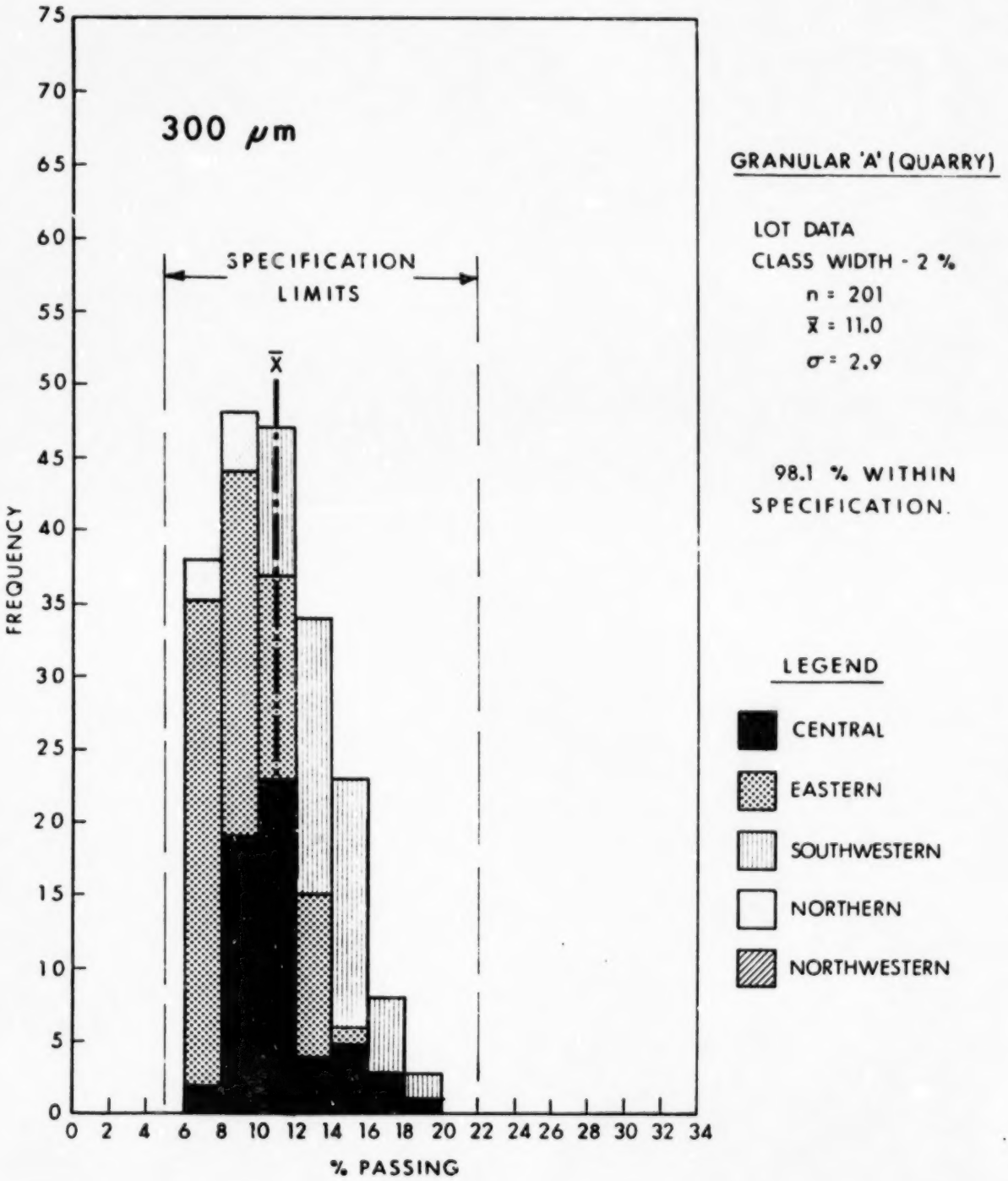
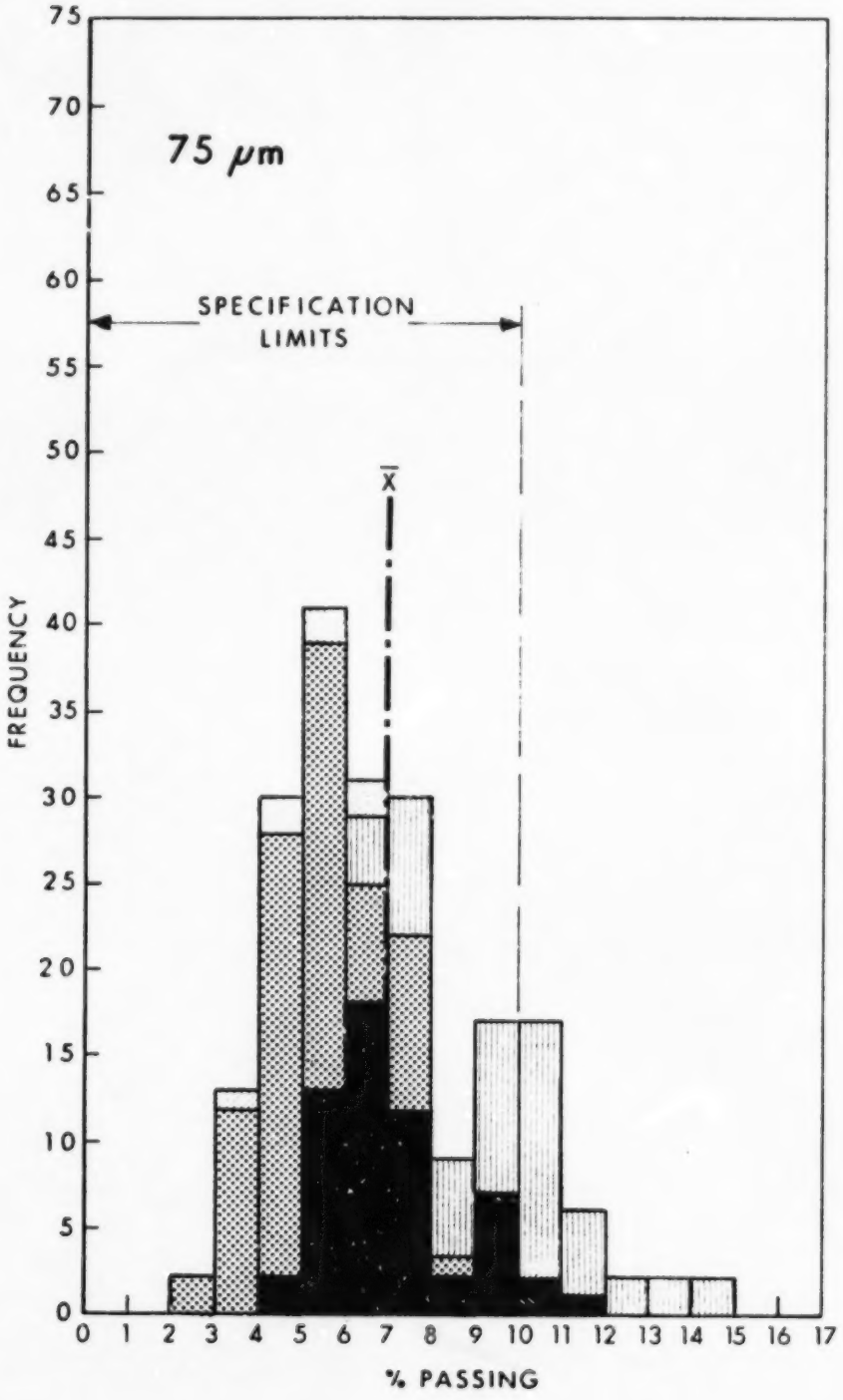

300 μm
SPECIFICATION LIMITS
X̄
FREQUENCY
% PASSING
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
GRANULAR 'A' (QUARRY)
LOT DATA
CLASS WIDTH - 2 %
n = 201
X̄ = 11.0
σ = 2.9
98.1 % WITHIN SPECIFICATION.
LEGEND
CENTRAL
EASTERN
SOUTHWESTERN
NORTHERN
NORTHWESTERN

Fig. 17 e



GRANULAR 'A' (QUARRY)

LOT DATA
CLASS WIDTH - 2 %
n = 202
$\bar{X}$ = 7.0
σ = 2.5

88.5 % WITHIN SPECIFICATION.

LEGEND

- CENTRAL
- EASTERN
- SOUTHWESTERN
- NORTHERN
- NORTHWESTERN

Fig. 17 f

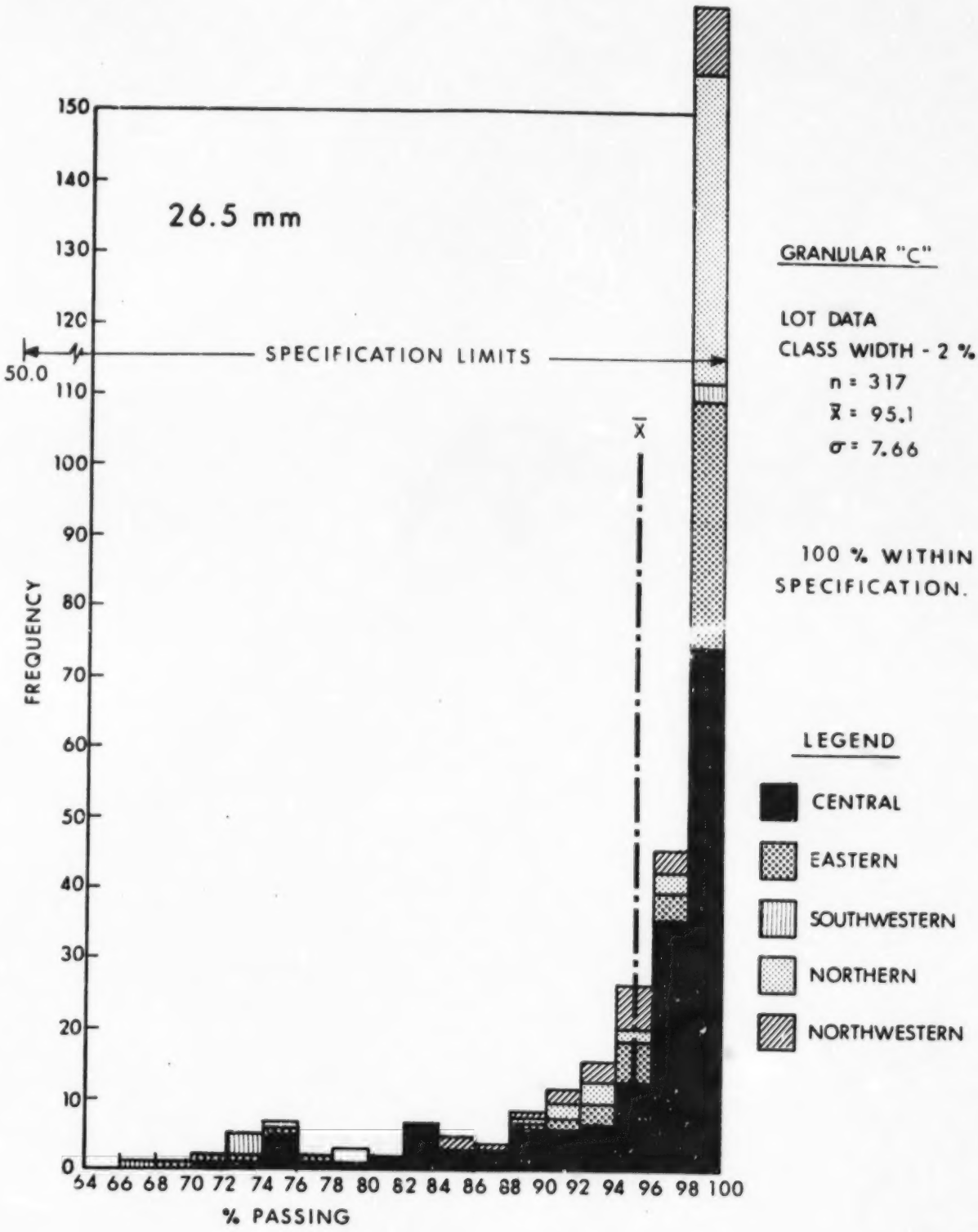

26.5 mm
SPECIFICATION LIMITS
50.0
FREQUENCY
% PASSING
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100
GRANULAR "C"
LOT DATA
CLASS WIDTH - 2 %
n = 317
X̄ = 95.1
σ = 7.66
100 % WITHIN SPECIFICATION.
LEGEND
CENTRAL
EASTERN
SOUTHWESTERN
NORTHERN
NORTHWESTERN

Fig. 18 a

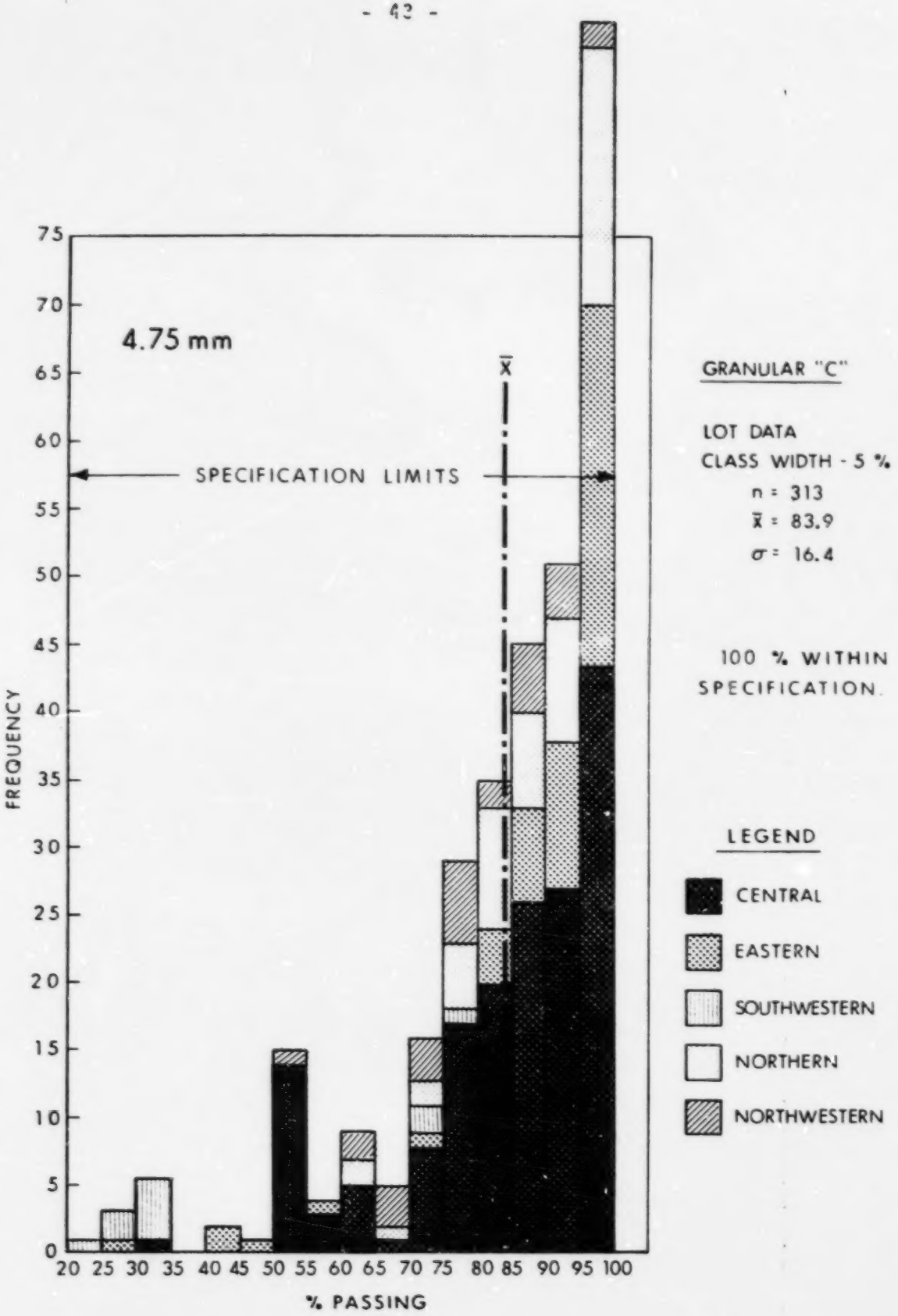

4.75 mm
$\bar{X}$
SPECIFICATION LIMITS
FREQUENCY
% PASSING
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
GRANULAR "C"
LOT DATA
CLASS WIDTH - 5 %
n = 313
$\bar{X}$ = 83.9
σ = 16.4
100 % WITHIN SPECIFICATION.
LEGEND
CENTRAL
EASTERN
SOUTHWESTERN
NORTHERN
NORTHWESTERN

Fig. 18 b

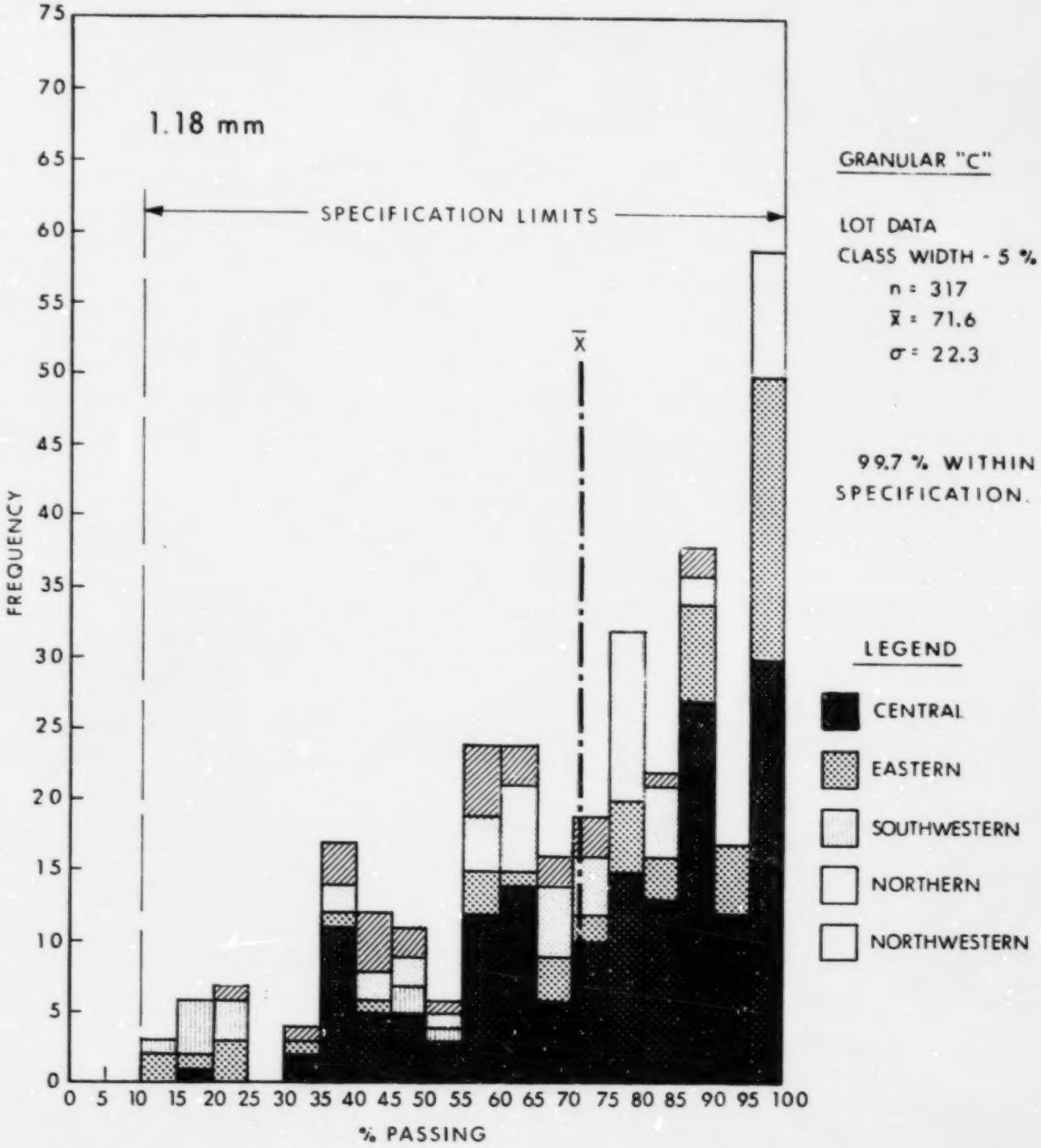

1.18 mm
SPECIFICATION LIMITS
X̄
FREQUENCY
% PASSING
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
GRANULAR "C"
LOT DATA
CLASS WIDTH - 5 %
n = 317
X̄ = 71.6
σ = 22.3
99.7 % WITHIN SPECIFICATION.
LEGEND
CENTRAL
EASTERN
SOUTHWESTERN
NORTHERN
NORTHWESTERN

Fig. 18 c

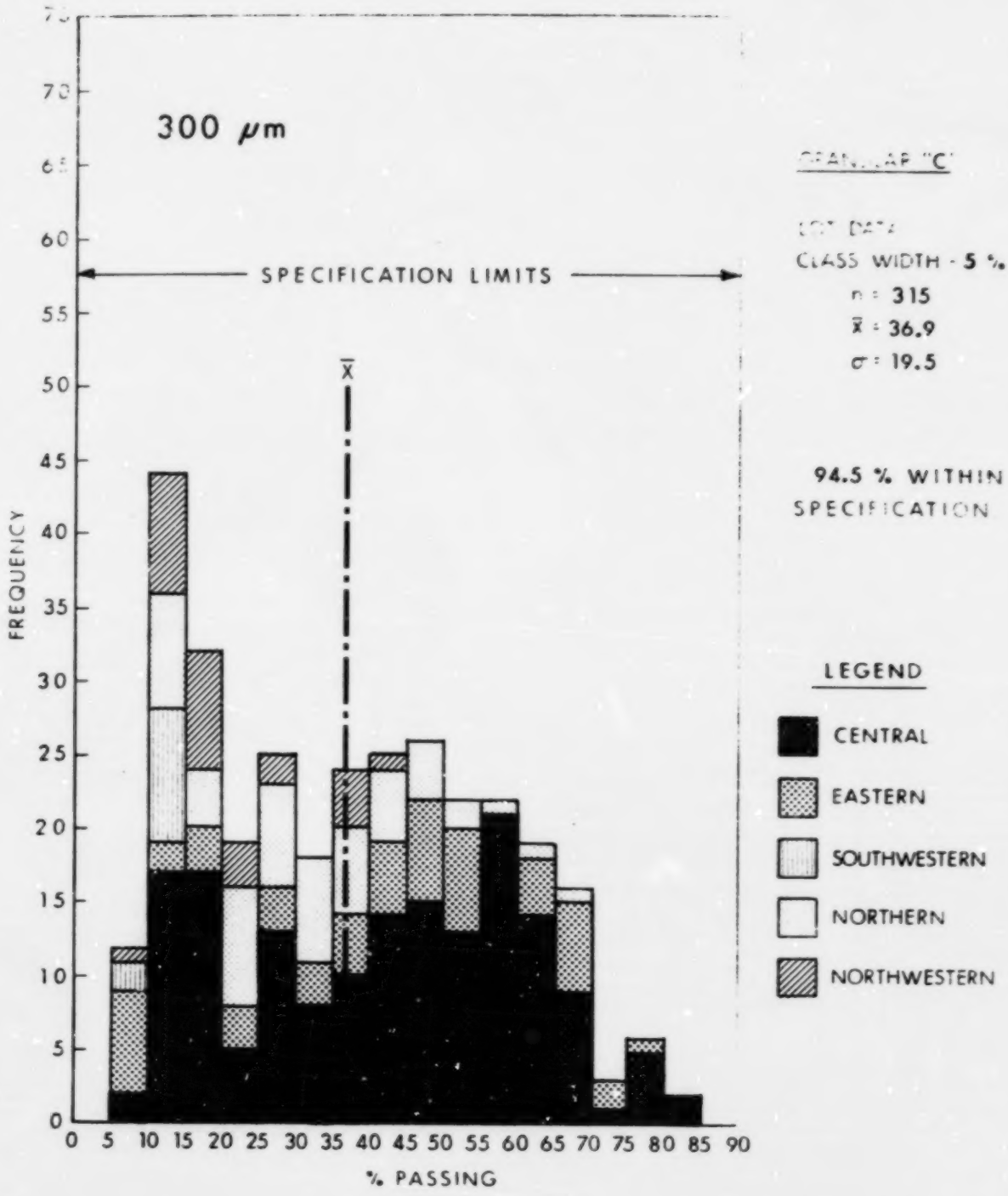

300 μm
SPECIFICATION LIMITS
X̄
FREQUENCY
% PASSING
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
0 5 10 15 20 25 30 35 40 45 50 55 60
GRANULAR "C"
LOT DATA
CLASS WIDTH - 5 %
n = 315
x̄ = 36.9
σ = 19.5
94.5 % WITHIN SPECIFICATION
LEGEND
CENTRAL
EASTERN
SOUTHWESTERN
NORTHERN
NORTHWESTERN

Fig. 18 d

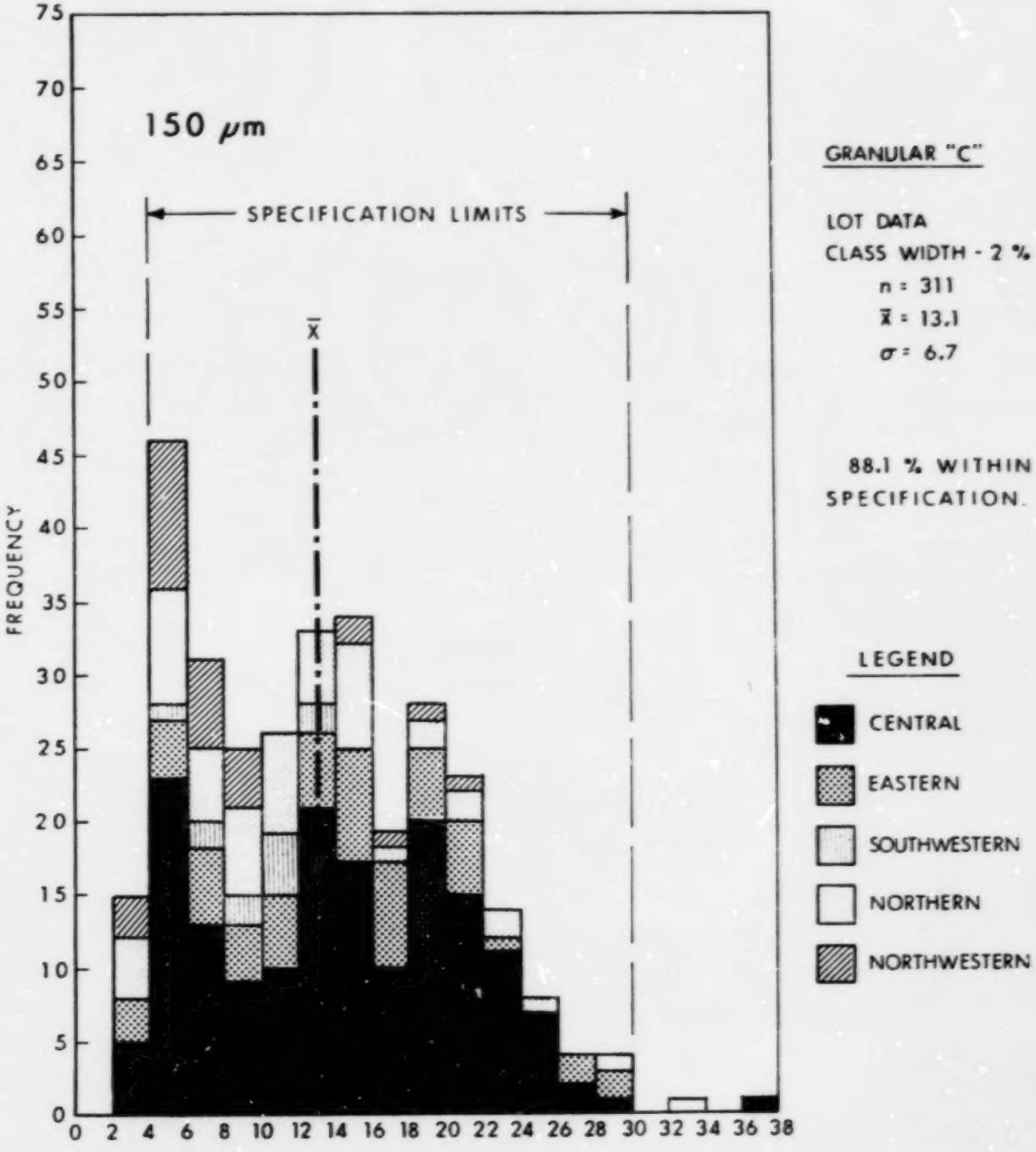
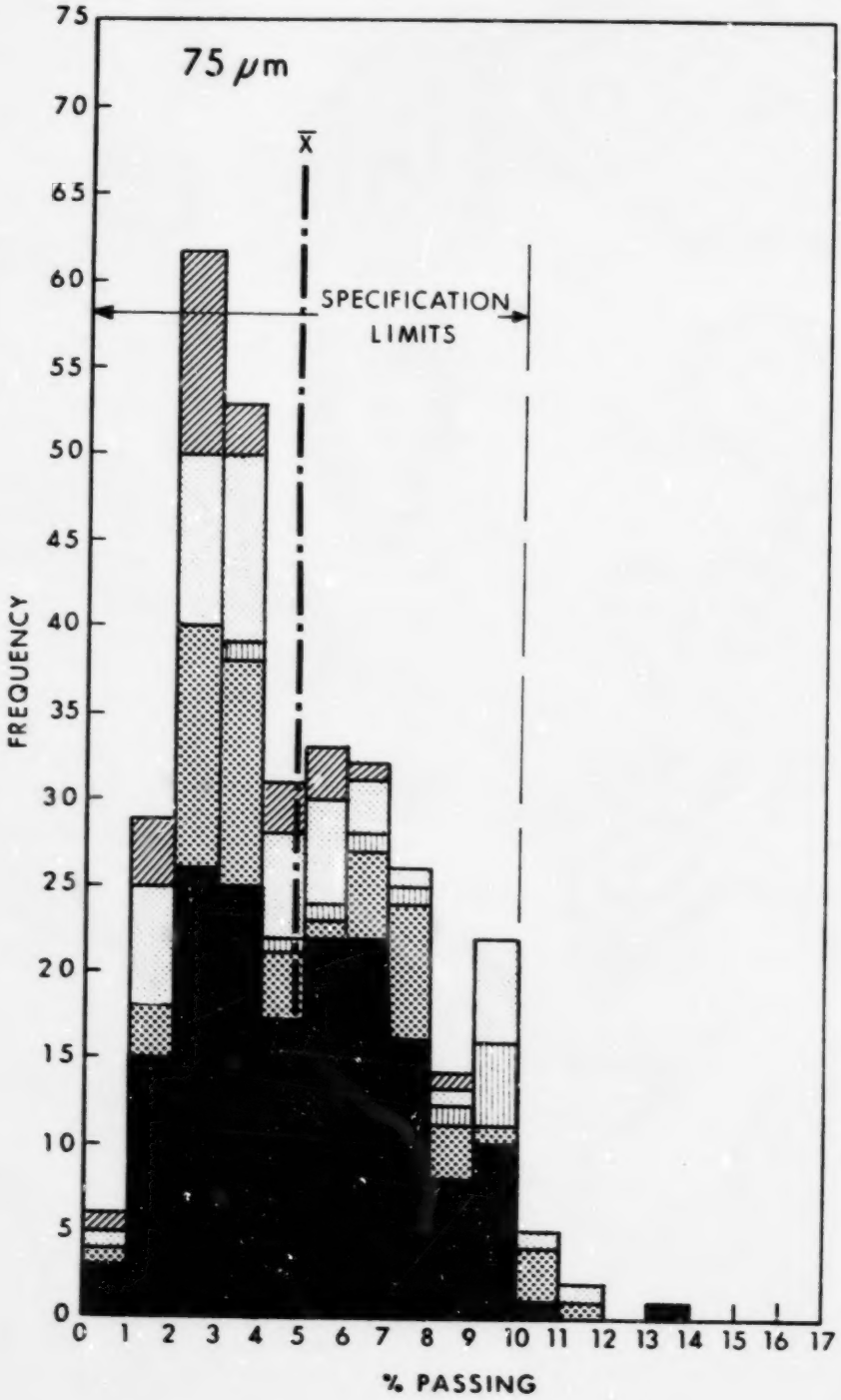

150 μm
SPECIFICATION LIMITS
X̄
FREQUENCY
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
GRANULAR "C"
LOT DATA
CLASS WIDTH - 2 %
n = 311
X̄ = 13.1
σ = 6.7
88.1 % WITHIN SPECIFICATION.
LEGEND
CENTRAL
EASTERN
SOUTHWESTERN
NORTHERN
NORTHWESTERN

Fig. 18 e



GRANULAR "C"

LOT DATA
CLASS WIDTH - 1 %
n = 316
$\bar{X}$ = 4.8
σ = 2.6

97.7 % WITHIN SPECIFICATION.

LEGEND

CENTRAL
EASTERN
SOUTHWESTERN
NORTHERN
NORTHWESTERN

Fig. 18 f

5. COMMENTS

A total of six thousand five hundred and ninety-two gradation tests were performed throughout the province during 1980. Figure 19 shows the breakdown of gradation tests received at Head Office.

REGION	GRANULAR			16mm CRUSHED		TOTALS
	A	B	C	A	B	
Central	1,664	300	724	-	-	2,668
Southwestern	640	52	44	-	60	796
Eastern	596	-	240	24	144	1,004
Northern	736	12	284	224	32	1,288
Northwestern	524	-	140	84	68	816
TOTALS	4,160	364	1,432	332	304	6,592

Fig. 19

1980 Gradation Tests

Each test had to comply to a gradation and a range specification for each designated sieve size and that for each test there is an average of six specified sieves; multiply the number of gradation tests by six for gradation specifications and the same again for the range criteria, which totals seventy-nine thousand one hundred and four test results that were required to meet specifications. (6 x 6592 = 39552 x 2 = 79,104)

No problems were encountered in meeting the acceptable range criterion as less than one half of one percent of all results were outside specifications. The acceptable ranges used for 1980 were based on the percentage spread of the gradation acceptance bands and not on statistical parameters. A range analysis for granular 'A' indicates that most ranges could be reduced, some considerably. Granular subbase materials have acceptable ranges as large as 90 due to wide gradation bands. A range analysis should be carried out on granular 'B' and 'C' materials to develop realistic acceptance ranges using statistical parameters.

Copies of forms used in this report for the purpose of collecting and recording data are available to the regions upon request.

Appendix 'B', 'C' & 'D' contain excerpts from Phases of Statistical Analysis, by Howard Reed and Malcolm MacLean, May 1981.

6. ACKNOWLEDGEMENTS

The preparation of a large portion of this report was made possible by the willing co-operation, interest and support of the following:

Mr. A.K. Barsvary - Senior Soils Engineer
Mr. M. MacLean - Soils Engineer
Mr. S. Osellame - Drafting Supervisor
Miss J. Hirons - Student Typist

APPENDIX 'A'

1980 GUIDELINES

1. Initial Acceptance (Early Production Acceptance)

Initial acceptance of a source should be based on 4 tests from one lot of the material to be produced. Examples of a lot for initial acceptance would be:

a) A day's production of Granular 'A' in a wayside pit.

b) The material delivered to a contract in a single day from a commercial source.

c) An existing stockpile in a commercial source.

d) A suitable open face for subbase material from a wayside pit or commercial source.

2. Lot Size

The recommended lot sizes for acceptance of granular base and subbase materials is 4000 tonnes or one day's production if less than 4000 tonnes. Regardless of daily production the lot size may be increased up to a maximum of 10 000 tonnes if testing facilities are limited and the product is well within specification limits. If one day's production is more than 10 000 tonnes, it should be accepted on the basis of lots of 10 000 tonnes or less.

For pit-run subbase materials only, when the deposit is uniform and well within specification limits, a maximum lot size of 20 000 tonnes may be used following initial acceptance of the first few lots with no apparent problems.

Lot sizes greater than 4000 tonnes may be chosen before the start of testing in cases where there is ample previous experience of material from the source being well within specification limits.

Each lot should be divided into four approximately equal sublots and one sample should be taken from each sublot.

Individual test results and lot means are to be recorded on gradation control charts.

3. Location of Samples for Testing

Samples for testing during production will be obtained at the source by sampling base material as it is crushed and placed in stockpile and by sampling subbase material at the pit face during production. End of belt samples should be avoided since there are many simple but difficult to detect ways by which the crusher operator can vary the product during the period that the sample is being taken. Composite samples taken from a recently produced area of the stockpile are preferred where possible.

Material from commercial sources will normally be sampled either during production, as above, or from existing stockpiles.

Only under the following circumstances shall material be sampled after placing in the road:

a) A commercial source with several stockpiles or several pit faces, some meeting our specifications and others not, with no guarantee that we will only receive the acceptable material.

b) Several sources of supply to one contract making sampling at the source impractical.

c) A commercial source supplying to other customers with a record of selling material, previously tested by ourselves, to others.

d) A contractor with a record of flooding the contract with very large quantities of material in a single day, making other methods of testing impractical.

e) The source of supply is variable in quality and close to the specification limit, and the contractor does not cooperate in controlling the product within the specification limits, making acceptance at the source very difficult.

f) When the contractor is loading base material directly from a crusher or from a small storage bin and no testing can be carried out before delivery of the material to the road.

The contractor shall be warned in writing prior to the use of road sampling. Road samples should be taken from material spread but not compacted, where possible. Tests from end of belt, stockpile or road samples, should not be mixed in considering the acceptance of any particular lot.

4. Random Sampling

Sampling should be carried out on a random basis. Where sampling at the source is used, samples should be taken at random times related to the amount of material being produced. Where road sampling is used, samples may be taken from tonnages selected at random or may be taken from areas selected at random on the grade. Whichever method of random sampling is used, tables of random numbers must be employed.

5. Production Acceptance and Rejection

The contractor should be kept informed of all test results.

Individual lots should be accepted if, on each specification sieve, the mean of the 4 tests falls within the specification limits and the range* of the 4 tests is no greater than the specification range.**

Where a lot does not meet these requirements, removal of the material from stockpile or from the road is mandatory, except under the conditions which follow, and the contractor must be notified immediately.

In the case of a stockpile, where the deviation is sufficiently small that the Ministry considers there will be only minor detriment to the performance of the highway if the material is incorporated in the work, and if the contractor elects to negotiate the price rather than remove the material, the material may be accepted at an appropriately adjusted price. If the material cannot be accepted on this basis and it is not practical to remove the rejected lot from the stockpile, the stockpile must be rejected.

The range is the difference between the highest and lowest values. For example, if the test values for Granular A material, on the 4.75 mm sieve, are 38%, 58%, 62% and 50% passing, then the mean is 52%, which is within the specification limits of 33 to 55%. However, the range of the 4 tests is 62 - 38 = 24%, which is greater than the specification range (55 - 33 = 22%). Therefore the lot should not be accepted.

**For Granular A and 16 mm Crushed A & B, tolerances are incorporated in the control charts for those sieves for which 100% passing is specified.*

In the case of material to be removed from the road, further tests should be taken from the lot. The procedure for retesting is to take 3 additional random samples from each sublot and consider the mean of the 4 test results (the 3 new tests plus the original test) as representative of each sublot. Individual sublots which do not meet the requirements for mean and range must be removed except that where the deviation is sufficiently small that the Ministry considers there will be only minor detriment to the performance of the highway if the material is incorporated in the work, and if the contractor elects to negotiate the price rather than remove the material, the material may be accepted at an appropriate adjusted price. The sublot size should not be greater than 2500 tonnes where material may be required to be removed from the road.

6. Incomplete Lots

Occasionally a change in the normal pattern of lot size may take place due to the contractor's operation. For example a breakdown in equipment, poor weather or some other cause may stop production of granular material at a time when less than four samples have been taken. If production is unlikely to restart for a few days the inspector may accept the material previously placed as an incomplete lot provided the mean of whatever number of tests may have been taken falls within the specification limits and their range is no greater than the specification range for each sieve.

If this is not the case, further samples should be taken at random from the previous production to give a total of four test results, and acceptance or rejection of the incomplete lot should be made on the four results in the normal way.

7. Individual Loads

Nothwithstanding the above guidelines, any load which is observed visually by the inspector to be outside the specification limits should be rejected and removed from the contract without payment.

APPENDIX 'B'

GUIDELINES FOR FREQUENCY TABLE DEVELOPMENT

1. DETERMINE THE RANGE OF THE DATA (THE DIFFERENCE BETWEEN THE LARGEST AND SMALLEST VALUE).

2. DECIDE ON THE NUMBER OF CLASSES INTO WHICH THE DATA WILL BE DIVIDED. A RULE OF THUMB STATES THAT THE NUMBER OF CLASSES SHOULD VARY FROM 5 TO 15, DEPENDING ON THE FORM OF THE DATA.

3. DETERMINE THE TENTATIVE CLASS INTERVAL (THE SPREAD BETWEEN THE LOWER AND HIGHER VALUES IN A CLASS) BY DIVIDING THE NUMBER OF CLASSES YOU THINK YOU NEED INTO THE RANGE OF THE DATA. THE CLASS INTERVALS SHOULD BE KEPT THE SAME.

4. ESTABLISH THE CLASS MIDPOINTS SO THAT THE LOWER LIMIT OF THE LOWEST CLASS IS A NUMBER WHICH IS LOWER THAN THE LOWEST DATA VALUE TO BE CLASSIFIED.

5. WRITE ALL THE CLASSES INTO EASY TO READ TERMS, INSURE THAT THE CLASSES ARE MUTUALLY EXCLUSIVE, THAT IS, THE CLASS LIMITS ARE DEFINED SO THAT A VALUE CAN PLACED IN ONLY ONE CLASS.

EXAMPLE:	CLASS LIMITS	REMARKS
a.	37 - 40 40 - 43	ACCEPTABLE BUT REQUIRES A DECISION RULE
b.	37 - 39.99 40 - 42.99	ACCEPTABLE, USE ONE DECIMAL POINT MORE THAN ORIGINAL DATA

TABULAR FORM

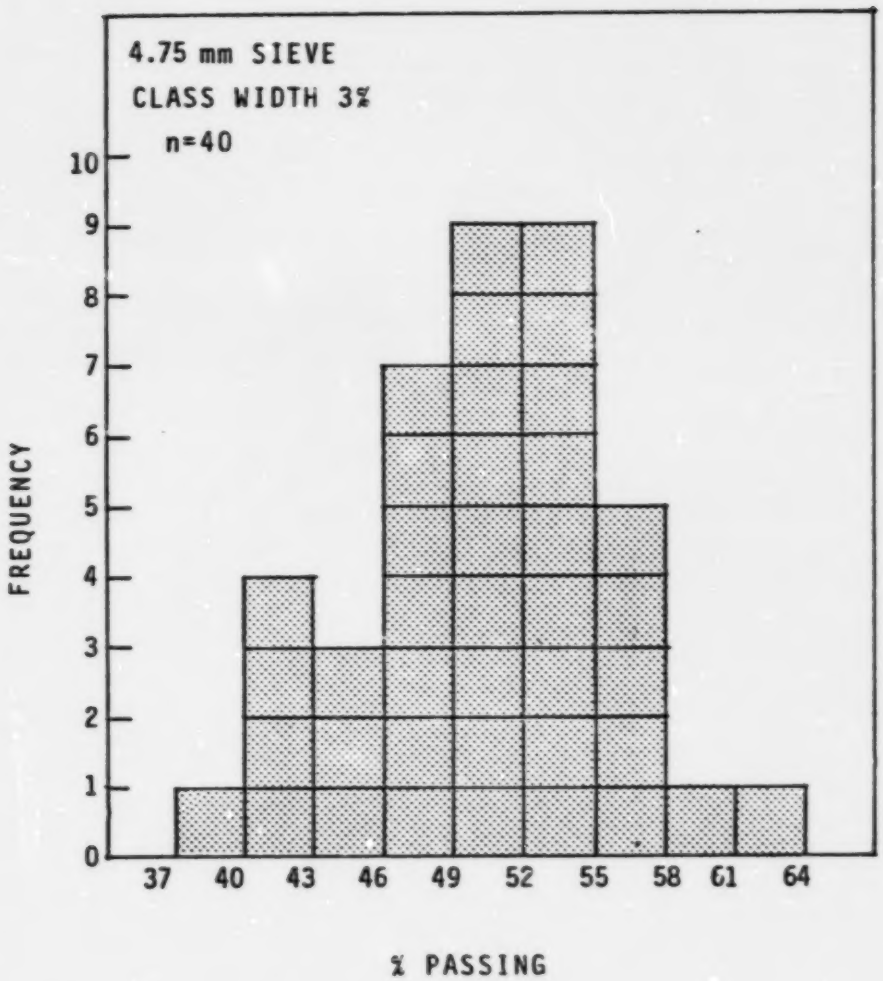
FREQUENCY TABLE

% PASSING 4.75 mm SIEVE CLASS WIDTH - 3%

CLASS NO.	CLASS LIMITS	TALLIED FREQUENCY	CLASS FREQUENCY	CLASS MID POINT
1	37 - 40	I	1	38.5
2	40 - 43	IIII	4	41.5
3	43 - 46	III	3	44.5
4	46 - 49	~~IIII~~ II	7	47.5
5	49 - 52	~~IIII~~ IIII	9	50.5
6	52 - 55	~~IIII~~ IIII	9	53.5
7	55 - 58	~~IIII~~	5	56.5
8	58 - 61	I	1	59.5
9	61 - 64	I	1	62.5
			n = 40	

GRAPHICAL FORM

FREQUENCY HISTOGRAM



APPENDIX 'C'

ANALYSIS EQUATIONS

FOR UNGROUPED SAMPLE DATA

$$\bar{X} = \frac{\Sigma X_i}{n}$$

$$\sigma = \sqrt{\frac{\Sigma (X_i - \bar{X})^2}{n - 1}}$$

WHERE: X_i = DATA

$\bar{X}$ = MEAN

n = NUMBER OF DATA

σ = STANDARD DEVIATION

Σ = SUMMATION OF DATA

FOR GROUPED SAMPLE DATA

$$\bar{X} = \frac{\Sigma f_i m_i}{n}$$

$$\sigma = \sqrt{\frac{\Sigma (m_i - \bar{X})^2 f_i}{n - 1}}$$

WHERE:

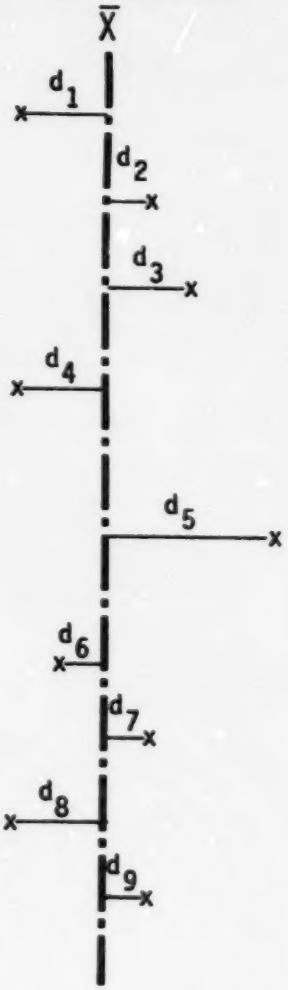
f_i = FREQUENCY OF OCCURRENCE IN CLASS i

m_i = CLASS MIDPOINT OF CLASS i

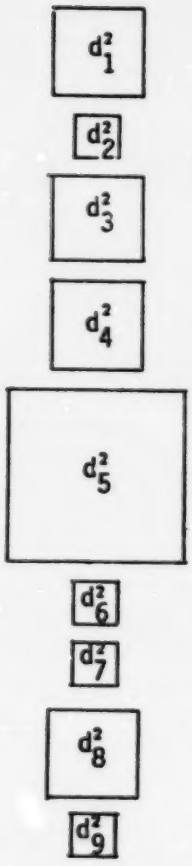
OTHER SYMBOLS AS ABOVE

THE CONCEPT OF STANDARD DEVIATION

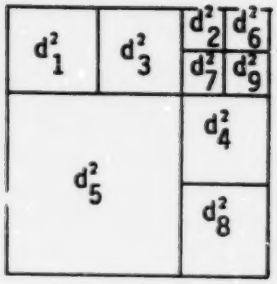
① DIFFERENCES FROM AVERAGE



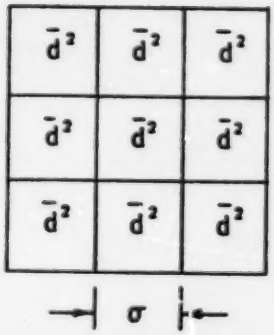
② SQUARES OF DIFFERENCES



③ SUM OF SQUARES OF DIFFERENCES



④ AVERAGE SQUARE OF DIFFERENCES



⑤ STANDARD DEVIATION

$$= \sqrt{\bar{d}^2}$$

CALCULATION BY HAND OF UNGROUPED DATA

LOT VALUES USED

STEPS	① TEST RESULTS X_i	② MEAN $\bar{X}$	③ DIFFERENCE FROM MEAN $(X_i - \bar{X})$	④ DIFF.^{2} $(X_i-\bar{X})^2$
	52.4	50.2	2.2	4.84
	55.4		5.2	27.04
	52.3		2.1	4.41
	45.5		-4.7	22.09
	52.1		1.9	3.61
	51.5		1.3	1.69
	50.5		0.3	0.09
	48.6		-1.6	2.56
	46.6		-3.6	12.96
	47.1		-3.1	9.61
	SUM = 502.0			SUM = 88.819
	n = 10			

② $\bar{X} = \dfrac{\Sigma X_i}{n} = \dfrac{502}{10} = 50.2$

⑤ $\sigma = \sqrt{\dfrac{\Sigma (X_i-\bar{X})^2}{n-1}} = \sqrt{\dfrac{88.819}{9}} = \sqrt{9.8687} = 3.14$

METHOD OF CALCULATING THE MEAN AND STANDARD DEVIATION USING THE TEXAS INSTRUMENTS TI-55 CALCULATOR

ENTER	PRESS		DISPLAY	COMMENTS
	2nd	CA	0	clear
1st Data	Σ+		1	1st entry
2nd Data	Σ+		2	2nd entry
3rd Data	Σ+		3	3rd entry
Incorrect Data	2nd	Σ-	2	removes 3rd entry
Correct Data	Σ+		3	Correct 3rd entry
4th Data	Σ+		4	4th entry
etc to last data entry				
Last Data	Σ+		18	18th entry (last)
	2nd	MEAN	VALUE	MEAN value
	2nd	S.DEV	VALUE	STANDARD DEVIATION

THE ABOVE EXAMPLE SHOWS A CORRECTION FOR AN INCORRECT ENTRY, CORRECTIONS OF INCORRECT ENTRIES CAN BE MADE IF DISCOVERED BEFORE PRESSING THE SUMMATION KEY [Σ+] BY PRESSING THE CLEAR ENTRY KEY [CE]. IT IS BEST NOT TO BE INTERRUPTED WHILE ENTERING SETS OF DATA.

WHEN IN DOUBT START OVER.

FREQUENCY TABLE

CLASS NO.	CLASS LIMITS	TALLIED FREQUENCY	CLASS FREQUENCY	CLASS MID POINT
1	43 - 46	I	1	44.5
2	46 - 49	III	3	47.5
3	49 - 52	II	2	50.5
4	52 - 55	III	3	53.5
5	55 - 58	I	1	56.5
			10	

CALCULATION BY HAND OF GROUPED DATA

STEPS	①	②	③	④	⑤	⑥
CLASS NO.	MID POINT m_i	FREQ. f_i	$m_i f_i$	MEAN $\bar{X}$	$(m_i - \bar{X})$	$(m_i - \bar{X})^2 f_i$
1	44.5	1	44.5	50.5	-6.0	36
2	47.5	3	142.5		-3.0	27
3	50.5	2	101.0		0.0	0
4	53.5	3	160.5		3.0	27
5	56.5	1	56.5		6.0	36
SUMS		10	505.0			126

④ $$\bar{X} = \frac{\Sigma \; m_i f_i}{n} = \frac{505.0}{10} = 50.5$$

⑦ $$\sigma = \sqrt{\frac{\Sigma \; (m_i - \bar{X})^2 f_i}{n - 1}} = \sqrt{\frac{126}{9}} = \sqrt{14} = 3.74$$

PROGRAM FOR GROUPED DATA

TEXAS INSTRUMENTS CALCULATOR TI-55

	ENTER ▼	PRESS				
START		2nd	CLR			
1st CLASS	f_1		SUM	3	×	f = class frequency
	m_1	=	SUM	1	×	
	m_1	=	SUM	2		m = mid values of each class
2nd CLASS	f_2		SUM	3	×	
	m_2	=	SUM	1	×	
	m_2	=	SUM	2		
etc.						
	f_h		SUM	3	×	
LAST CLASS	m_h	=	SUM	1	×	
	m_h	=	SUM	2		

END OF DATA ENTRY

CALCULATE	PRESS
MEAN ($\bar{x}$)	RCL 1 + RCL 3 = STO 4
STANDARD DEVIATION (σ)	RCL 2 - (RCL 1 x^2 + RCL 3) = ÷ (RCL 3 - 1) = $\sqrt{x}$

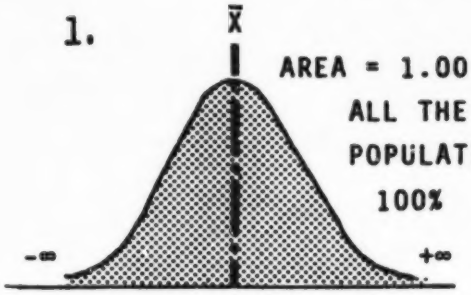
FOR COMPUTATION BY CALCULATOR THE ORIGINAL FORMULA WAS REWRITTEN THUS:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{h} (m_i - \bar{x})^2 f_i}{n-1}} = \sqrt{\frac{\sum_{i=1}^{h} m_i^2 f_i - \frac{\left(\sum_{i=1}^{h} m_i f_i\right)^2}{n}}{n-1}}$$

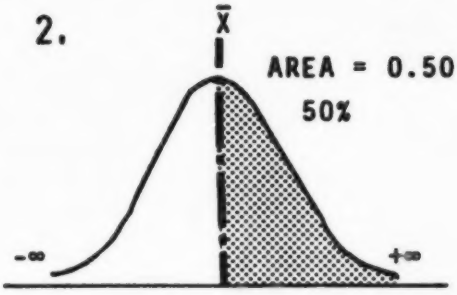
APPENDIX 'D'

AREA UNDER A NORMAL CURVE

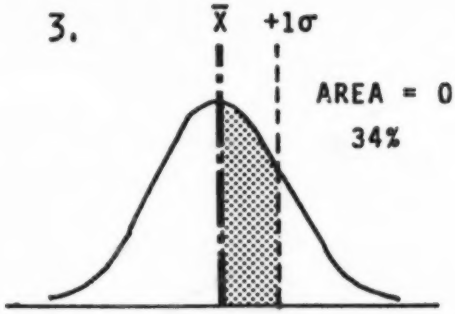
1.



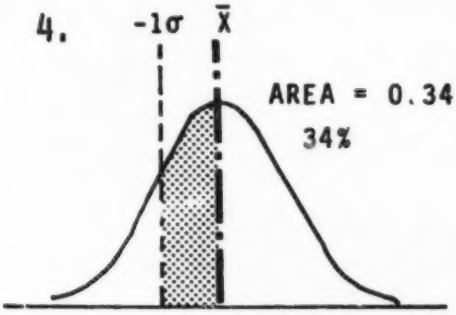
2.



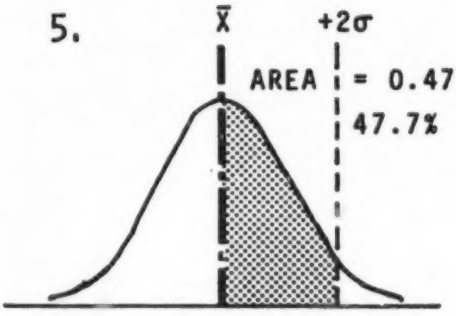
3.



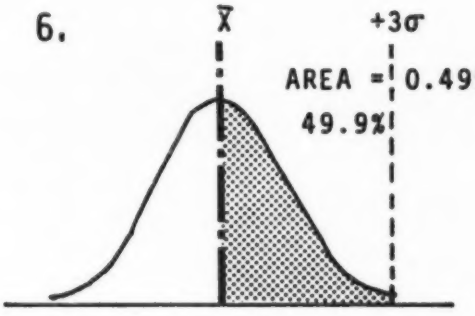
4.



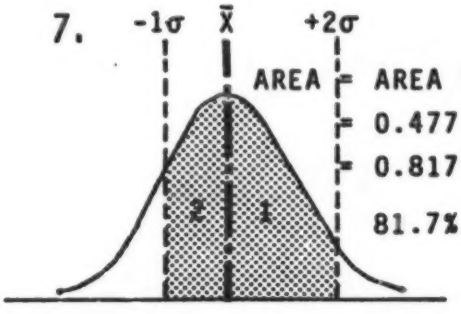
5.



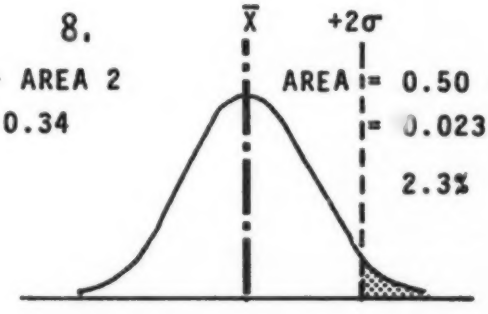
6.



7.

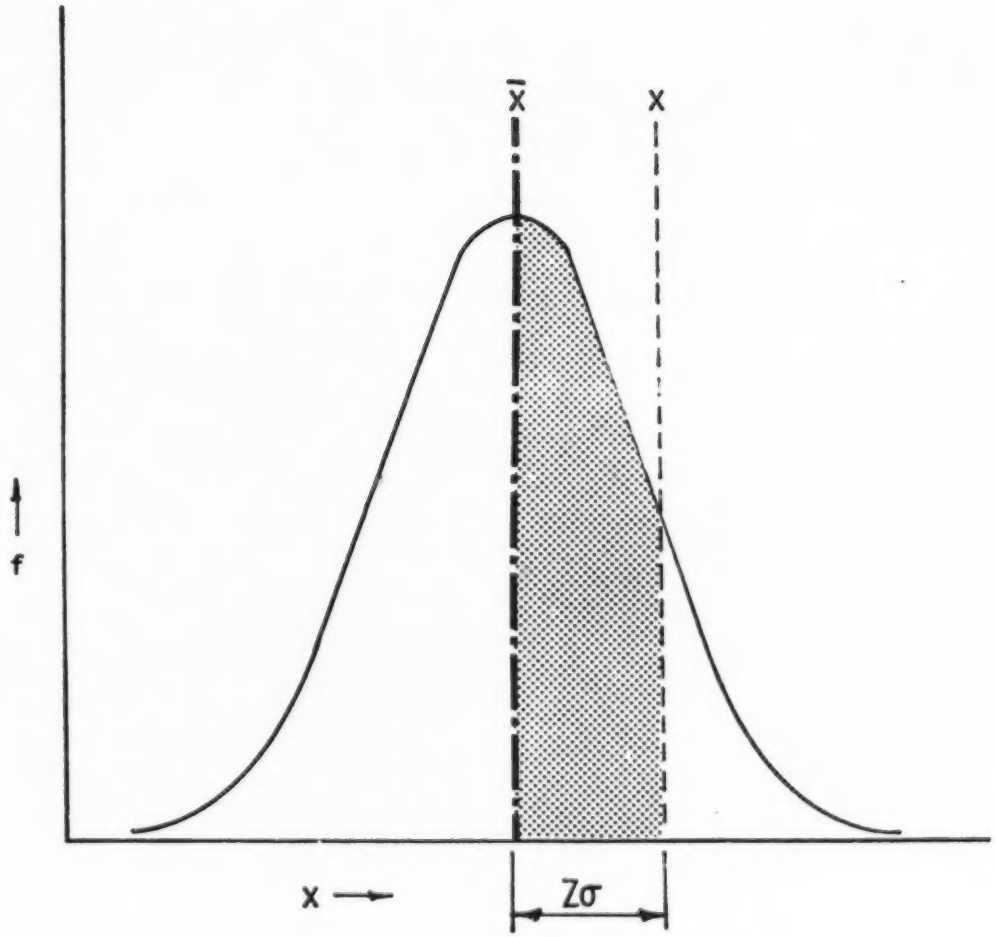


8.



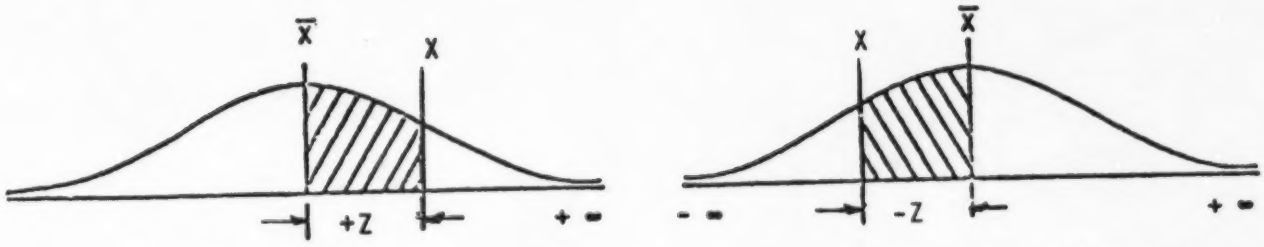
THE 'Z' FACTOR

$$Z = \frac{x - \bar{x}}{\sigma}$$



THE AREA UNDER THE CURVE BETWEEN MEAN ($\bar{X}$) AND ANOTHER POINT (X), DEPENDS ON 'Z' WHICH IS ARITHMETIC DIFFERENCE BETWEEN X AND $\bar{X}$, DIVIDED BY THE STANDARD DEVIATION (σ).

THE 'Z' TABLES



Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2517	.2549
0.7	.2580	.2611	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.49865	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990
3.1	.49903	.4991	.4991	.4991	.4992	.4992	.4992	.4992	.4993	.4993
3.2	.49931									
3.3	.49952									
3.4	.49966									

EXAMPLE

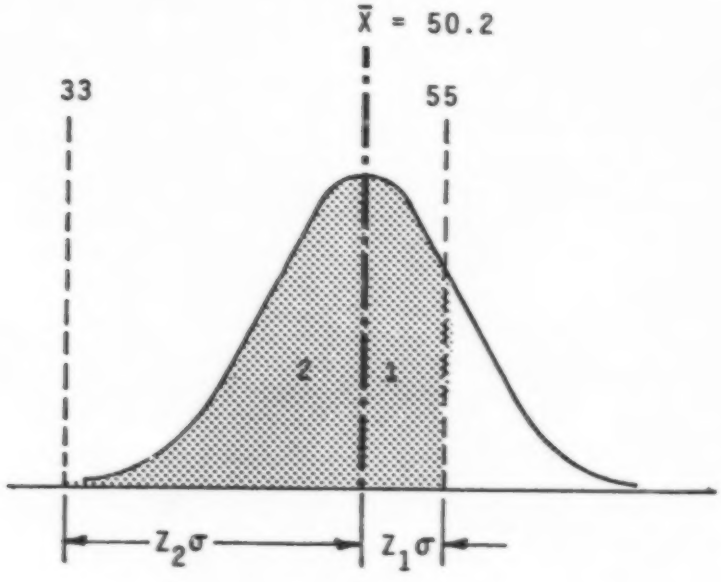
RESULTS OF GRADATION TESTS
ON GRANULAR 'A'
(SOURCE REED SAND AND GRAVEL)

PASSING 4.75 mm SIEVE:

MEAN 50.2%

STANDARD DEVIATION 5.3%

PROBLEM: TO DETERMINE STATISTICALLY WHAT PERCENTAGE OF THE MATERIAL IS WITHIN SPECIFICATION ON THE 4.75 mm SIEVE. (LIMITS 33% - 55%).



SOLUTION:

1. DETERMINE % BETWEEN MEAN AND UPPER SPECIFICATION LIMIT.

$$Z_1 = \frac{\text{UPPER SPECIFICATION LIMIT } (x) - \text{MEAN } (\bar{x})}{\text{STANDARD DEVIATION } (\sigma)}$$

$$= \frac{55 - 50.2}{5.3} = \frac{4.8}{5.3} = 0.91$$

$Z_1 = 0.91$

FROM TABLE READ .3186

THUS 31.9% OF THE MATERIAL IS BETWEEN THE MEAN AND THE UPPER SPECIFICATION LIMIT.

2. DETERMINE % BETWEEN MEAN AND LOWER SPECIFICATION LIMIT.

$$Z_2 = \frac{\text{LOWER SPECIFICATION LIMIT } (x) - \text{MEAN } (\bar{x})}{\text{STANDARD DEVIATION } (\sigma)}$$

$$= \frac{33 - 50.2}{5.3} = \frac{-17.2}{5.3} = -3.24$$

$Z_2 = -3.24$

NOTE: MINUS SIGN INDICATES X IS TO THE LEFT OF $\bar{x}$.

FROM TABLE READ .49931

THUS 49.9% IS BETWEEN THE LOWER SPECIFICATION LIMIT AND THE MEAN.

3. ADD AREA 1 AND AREA 2

49.9 + 31.9 = 81.8%

THUS 81.8% OF THE MATERIAL IS WITHIN SPECIFICATION.

APPENDIX 'E'

SUGGESTED ADJUSTED PAYMENT

Adjusted Payment

Payment for lots or uncompleted lots which do not meet the specification requirements but which are not subject to rejection under (b) following, shall be adjusted as follows:

(a) Gradation

If the Contractor chooses to use a lot of Granular A which does not meet the specification requirements for gradation, or where such a lot cannot be totally excluded from the work, payment for that lot shall be made at a price equal to the contract price for Granular A less a percentage equal to the sum of the adjustment points determined on the following basis: For each 0.1% that the mean gradation falls outside the applicable limits for each sieve, adjustment points shall be applied according to the following table.

Ministry Sieve Designation	Adjustment Points per 0.1% Deviation from Specification Limits
37.5* mm	0.1
19.0 mm	0.1
9.5 mm	0.1
4.75 mm	0.5
1.18 mm	0.1
300 µm	0.1
75 µm	1.0

* Where the contract requires the maximum size to be 22.4 mm, the adjustment for the 37.5 mm sieve shall apply to the 22.4 mm sieve.

For each 0.1% that the range exceeds the maximum acceptable range for each sieve, 0.1 adjustment points shall be applied.

If the contractor chooses to use a lot of Granular A which does not meet the specification requirements for gradation, or where such a lot cannot be totally excluded from the work, payment for that lot shall be made at a price equal to the contract price for Granular A less the sum of the percentages prescribed above.

(b) Rejection

Lots or uncompleted lots which are subject to a price adjustment of more than 25% of the contract price, shall be rejected and shall not be incorporated in the work, or, where already incorporated shall be removed from the work.